



Energy audit of livestock production system in a mid-altitude Himalayan agro-ecosystem

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ABSTRACT

The present study analyses energy flows through livestock production system and works out energy audit in selected mid-altitude villages in the Pithoragarh district of the Kumaun Division of Uttarakhand lying in the Central Himalayan region. The livestock population (converted into livestock units) consumed 144638094.9 kJ/day or 52792904649 kJ in a year and, in turn, produced 8490715137.07 kJ in a year through dung, 2056277724 kJ through milk, 60704289.30 kJ through calf crop and 6416.35 kJ by means of draught power supply to various agricultural operations. The gross energy produced by livestock was 10607703567 kJ/year. Proportion of the output energy from dung (80%) was much more than from milk (19%). Contribution of calf crop and draught animal power (DAP) was minimal compared to the overall energy. The gross energetic efficiency of livestock production was 20.09%. Energy for maintenance and growth available for livestock was 25.15%. The study reveals that a substantial proportion of energy in a mountain agro-ecosystem flows through livestock.

Key words: Agro-ecosystem, Energy, Himalaya, Livestock

Livestock comprise one of the main components of the mixed farming system in the Himalayan mountains. They convert the energy of forest and grassland vegetation into useful products, like draught power, dung, milk and meat and thus play a dynamic role in the rangeland-based mountain agro-ecosystem.

Mountain farmers are livestock-dependent and are accustomed to rear large number of livestock which contribute to a good chunk of economy (Singh and Gaur 2008). As the only source of draught power in mountain agriculture, cattle play an important role in agricultural production, apart from yielding milk. One of the major reasons that make livestock farming compatible to mountain areas is the presence of rangelands over very large proportion of the geographical area (Singh *et al.* 2008, Singh 2018). Virtually entire feed and fodder needs of livestock are met from these rangelands. Crop residues, otherwise of no use for human beings, also support livestock feeding.

Nevertheless, at the same time, livestock are considered to be a burden on the lofty Himalayan ecosystem, as they have direct interaction with the environment and this interaction leads to the deterioration of the forest and grazing lands. The livestock in a mountain farming system, in fact, play a crucial

ecological role and contribute to the ecological integrity of an agro-ecosystem by maintaining nutrient and energy flows within the agro-ecosystem (Singh and Gaur 2008).

Animal scientists and economists often advocate culling of ‘useless’ animals. But the concept of ‘useless animals’ does not hold true for mountain farmers. Even if the ‘useless’ animals are not contributing to the economy in terms of draught power and milk, they are producing dung for manuring the cropland which is phenomenal to soil fertility management in the traditional setting of the mountains (Singh 2018, Rastogi *et al.* 2018). Organic movements going on the world over for which Himalayan areas are being regarded as a hub cannot sustain without manuring the croplands for which livestock’s role is very critical (Negi and Singh 2013).

Energy budgeting is influenced phenomenally by the production performance of livestock. Productivity of livestock, in fact, is a function of the whole agro-ecosystem. An understanding of the energy audit of livestock production systems is crucial to analyse the vital livestock-mediated flows in a mountain agro-ecosystem, which are indispensable for inducing and maintaining the ecological integrity of the whole system.

MATERIALS AND METHODS

Study area: The study area is located in the Pithoragarh district in the Kumaun Division of Uttarakhand. This district extends over a geographical area of 468293 ha, out of which 47.8% is under forests. The Uttarakhand state of India lies in the Indian Central Himalayan region.

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Selection of villages: The Gramsabha Durlekh in Pithoragarh district was purposely selected for the study. This Gramsabha has a cluster of five villages, viz. Bajani, Ajera, Hachila, Durlekh and Leemabhat. The selected agro-ecosystem is a typical case of mountain agriculture. The agro-ecosystem lies in the mid-altitude range (1400 to 2000). This is the altitude on which most of the mountain agriculture is concentrated.

Selection of households: From each of the villages, ten farm families were selected randomly and required information was collected on the pre-structured format. In this way, a total of fifty households were selected for collecting detailed information.

Data collection: The required information was collected from Government offices, Gramsabha office and from selected households. All agricultural outputs were recorded as per the estimates of the farmers, except for the amount of crop residues which was estimated based on the straw-grain ratio provided by Singh (1998). Livestock population for a village was derived on the basis of sample survey of households. Average milk production per day multiplied by average lactation length provided annual milk production per head.

RESULTS AND DISCUSSION

Inputs of livestock production system: Feed and fodder are the major inputs of a livestock production system. In order to estimate the amount of dry-matter consumed by livestock population, all classes of livestock were converted into livestock units following the formula of Singh (1998). There were 1694.15 livestock units in all the villages studied (Table 1).

Feed consumption data were based on close observation of the households on the day of the visit. Amount of feed consumed was converted into its energy values according to Mitchell (1979). A livestock unit, on an average, consumed about 9.1 kg feed per day. If the dry-matter of this feed is considered it would come out to be about 3.5 kg, which is in accordance with the rate of dry-matter consumption in relation to body weight of the animal. The whole population consumed 15496.75 kg feed/day or 5656313.75 kg in a year (Table 2). Converted into energy value, a livestock unit was found consuming 84608.58 kJ/day or 30882131.7 kJ/year. The whole livestock population converted into livestock unit consumed 144638094.9 kJ/day or 52792904649 kJ in a year (Table 3).

Straws of different crops make the most important livestock feed. Most of the energy for maintenance and production of the livestock population in the mountains of

Table 2. Average amount (kg) of different feed items consumed/animal/day on dry-matter basis

Feed item	Per livestock unit		Whole population	
	Per day	Per year	Per day	Per year
Straws	3.5	1277.5	5929.52	2164274.8
Green grass	2.5	912.5	4235.37	1545910.05
Oak leaves	2.0	730.0	3388.30	1236729.5
Hay	0.4	146.0	677.66	247345.9
Wheat flour	0.2	73.00	338.83	123672.95
Grains	0.3	109.5	588.24	214707.6
Soybean	0.2	73.0	338.83	123672.95
TOTAL	9.1	3321.5	15496.75	5656313.75

the Himalaya is derived from dry fodder, i.e., the straws. Dry fodders are the crop residues which contribute 57% of the total annual energy requirements of livestock. While green grass and oak leaves fulfill 11 and 10% of livestock energy needs, respectively, hay and food grains contribute 7% each and wheat flour and soybean contribute only 4% energy each to livestock production in a year.

Outputs of livestock production system: There are three outputs of the livestock production system: dung, milk and calf crop (Table 4). An animal (livestock unit equivalent) produced 1.540 kg of dung on dry-matter basis/day. The whole livestock population thus would produce 952281.71 kg dry-matter of dung in a year in the entire agro-ecosystem.

Milk production was 2.5 kg/head/day. Only 40% of all the animals were in milk stage. Average lactation length of a cow was 240 days. Annual milk production of the whole livestock population was equal to 618675 kg. In the livestock population, about 40% of the cows were in expected to calve in a year. This gave a figure of 678 new born calves in a year.

Amount of the dung produced by livestock population was converted into energy value (2.13 kcal/g) on its dry-matter basis, which for the whole population came out to be 8490715137.07 kJ in a year. Milk production multiplied by its energy value (794 kcal/kg) gave energy value of the total milk produced in a year, which was 2056277724 kJ. Energy value of a new born calf, according to Odend'hal (1972), was 89534.35 kJ, which multiplied by the calf crop of the year, would give energy harvested in the form of calves in the period of a year. The calf crop energy figure came out to be 60704289.30 kJ. Bullock energy input in the whole of the cultivated land of the study villages was taken as the energy produced by livestock for agricultural production, which was equal to 6416.35 kJ. The gross energy produced by livestock was 10607703567 (Table 5).

Table 1. Number of livestock units in the study villages

Livestock	Bajani	Ajera	Hachila	Durlekh	Limabhat	Total	Total livestock units*
Cattle	118	122.5	109	168	142	659.5	659.5
Buffalo	105.5	129.5	113.5	141	124	613.5	920.25
Goat	299	89	33	43	108	572	114.4

*1 Livestock unit, 1.0 cow/ 1.0 bullock/ 0.67 buffalo/ 0.2 goats.

Table 3. Energy equivalent of feed items in kJ

Feed item	Per livestock unit		Whole population	
	Per day	Per year	Per day	Per year
Straws	48951	17867115	82930266.72	30269547352.8
Green grass	9891	3610215	16756817.86	6116238521.82
Oak leaves	8408.4	3069066	14245090.86	5199458163.9
Hay	5822.88	2125351.2	9864832.15	3600663735.48
Wheat flour	3246.6	1185009	5500227.39	2007582997.35
Grains	4869.9	1777513.5	9548899.92	3485348470.8
Soybean	3418.8	1247862	5791960.02	2114065407.3
Total	84608.58	30882131.7	144638094.9	52792904649

Table 4. Livestock outputs of human use

Outputs	Per livestock unit		Whole population	
	Per day	Per year	Per day	Per year
Dung (kg)	1.540	562.1	2608.99	952281.71
Milk (kg)	2.50	600.00*	1695.00**	618675.00
Calves (no.)	—	—	—	678

*Lactation length was 240 days. **Only 40% of the cattle population was in milk stage.

The largest proportion of the output energy is received through dung (80%), followed by milk (19%). Contribution of calf crop and of draught animal power (DAP) was minimal compared to the overall energy.

Gross energetic efficiency of livestock production: Energy budget of livestock production has been presented in Table 6. Energy of useful production in a year was 10607703567 kJ, or 1060.77×10^7 kJ/year (Fig. 1).

We found that the gross energetic efficiency of livestock production was 20.09%. Energy for maintenance and growth available for livestock was 25.15%. This efficiency is higher than that reported earlier by Odend'hal (1972) on Singur (West Bengal) cattle and Singh and Sharma (1993) on crossbred cattle in temperate environment of the Himalayan mountains.

Table 5. Energy values (kJ) of livestock outputs

Output	Per livestock unit		Whole population	
	Per day	Per year	Per day	Per year
Dung ¹	13730.91	5011784.77	23262224.45	8490715137.07
Milk ²	8309.2	1994208	5633637.6	2056277724.00
Calves ³	—	—	—	60704289.30
Draught power	—	—	—	6416.35*
Total	22040.11	7005992.77	28895862.05	10607703567

¹8916.18 kJ/kg; ²3323.68 kJ/kg; ³89534.35 kJ per new born calf (Singh and Sharma 1993 based on Odend'hal, 1972). *Bullock draught power used in the preparation of the total cropland area of the study villages (i.e., 388.87 ha) multiplied by 16.50 kJ/ha, the rate of power output gave this figure.

Table 6. Gross energetic efficiency of livestock production in the mountain

Particulars	Values
Energy of useful production, (kJ)	10607703567
Energy of total consumption, (kJ)	52792904649
Gross energetic efficiency (%)*	20.09
Energy for maintenance and growth (%)**	25.15

*(Energy of useful production/Energy of total consumption) × 100; ** (Energy of useful production/Energy of total consumption – Energy of useful productivity) × 100.

The local livestock were provided the fodder which was originated from the agro-ecosystem itself. Energy contribution of straws was maximum during a year, which would not be effectively utilized by the livestock particularly in a season when it is not supplemented with green fodder. In certain season of the year when green fodder is not available and livestock have to depend only on poor quality fodder, their output in terms of milk would be reduced considerably. In such a season, energetic efficiency of livestock production is also likely to be reduced considerably.

Milk is the energy output of immediate human use. Dung produced is also not of less importance. The fertility of mountain soils in traditional system is maintained only by applications of manure of which dung is the main source. In a mountain agro-ecosystems, livestock play pivotal role in transferring nutrients of comparatively more stable forest ecosystems to the fragile croplands through manure.

Though the calves are important for stimulating milk letdown in their mothers, they do not contribute energetically on short-term basis. Adult male cattle contribute to the supply of draught power to mountain agriculture. Their role in supplying draught power is of vital importance in mountain agriculture which has no alternative to draught animal power system.

In an earlier study (Singh and Sharma 1993), it was concluded that the high-energy crossbred cattle are inappropriate for the mountain areas. Although the indigenous cattle reared in a traditional system are appropriate for mountain conditions, their feed conversion efficiency needs to be substantially improved through better nutrition. An improvement in their feed conversion efficiency would lead to an improvement in their gross energetic efficiency. As the sources of feed are available in the mountain agro-ecosystems, particularly in the forests/rangelands, improvement in their feed conversion efficiency is possible. A focus on the ecological regeneration of uncultivated areas and augmentation of fodder supply systems would be phenomenal in enhancing the overall performance of a mountain agro-ecosystem. A larger forest-cropland ratio would favour enhanced agro-ecosystem performance.

A substantial proportion of energy in a mountain agro-ecosystem, thus, flows through livestock component. The gross energetic efficiency was towards higher side as the

human labour incurred in livestock management was not taken into consideration. Further, conversion of all types of livestock into livestock units although was logical but this method would slightly deviate from the precision of energy consumption and production. Nevertheless, enormous energy flow through livestock is of special significance in the analysis of mountain agro-ecosystems.

Energy flow within different components: An attempt has been made to show energy flow through the agro-ecosystem under study (Fig. 1). Ecosystem function, in essence, is the play of energy. The sun is the ultimate source of ecosystem energy. Energy flowing through Earth's ecosystems is all owing to solar energy which is trapped by green plants and is then transferred from one trophic level to the other through food chain and interlocking pattern of food chains referred to as food web. But in an agro-ecosystem, humans are the major consumers. A typical mountain agro-ecosystem, as also the one in the study area has four major trophic levels, viz. forest/ grassland vegetation, field crops, livestock and humans. The first two trophic levels comprise producers and the two others, the consumers, human species being the 'top consumer'. The other consumers, such as wild animals, birds, etc. are not taken into consideration.

Unlike natural ecosystems, such as a forest, an agro-ecosystem involves import of energy (chemical fertilizers,

pesticides, etc.) and also exports some proportion of energy in the form of foods and other biomass. All ecosystem functions are manipulated by humans in their own favour.

A general mountain agro-ecosystem as being unfolded in this study generates enormous amount of energy within, which keeps the social life going on continuously. Rastogi *et al.* (2018) in their recent study have also appreciated enormous amounts of energy flowing through a mountain agro-ecosystem. Energy flows from cropland to households and livestock are on per ha basis, whereas the flows from and to livestock are on annual basis. Estimates of energy to come through chemical fertilizers and pesticides were made, but the whole amount of imported energy (food grains, sugar, edible oil, etc.) could not be estimated in this study. Energy generation through biomass requires considerable amount of energy input also. The ratio between the two is of critical importance and reflects the performance of the agro-ecosystem.

A major ecological principle states that environment is holocoenotic in nature, and therefore, any change in one component is bound to change the status of all other components; for example, deforestation leads to increased water run off (hence food problems), increased soil erosion (hence siltation of water bodies), disappearance of species (hence gene erosion), and atmospheric loading of CO₂

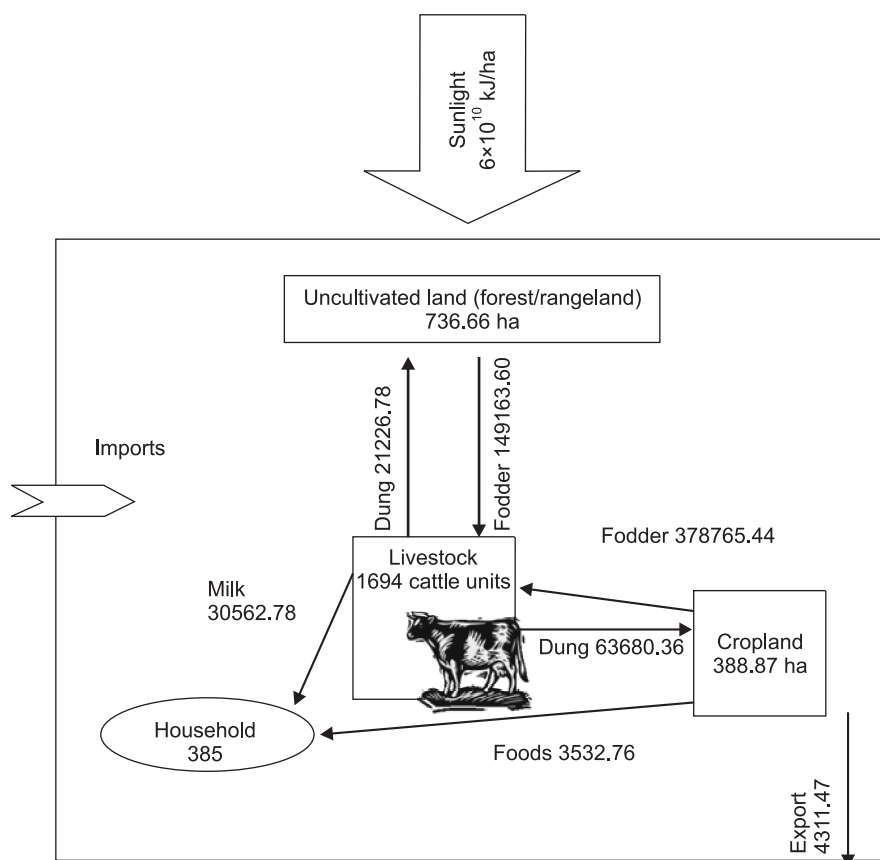


Fig. 1. Energy flow through different components of the mountain agro-ecosystem (All figures are $\times 10^5$ per ha for summer crops; underlined figures indicate annual energy flows through the entire agro-ecosystem).

(hence global warming) (Singh and Melkania 2005). Functions of individual agro-ecosystem components are not isolated. They are interconnected with one another. Functions of one component influence others' and are influenced by others. These functions are constantly monitored by human beings in their own interest.

The energy flow considerations in an agro-ecosystem are of phenomenal socio-economic importance. With an understanding of energy consumption and production by individual species (crop plants and animals) or component (cropland), we can work out the performance level of the same. Food security, social progress, human development and happiness are rooted into an agro-ecosystem and are influenced by ecosystem functioning, which, in turn, is influenced by resource management.

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