Integrated Farming Systems in the Andean Foothills of Colombia (Preliminary Results)

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Abstract

This paper describes changes in farming systems in a community in the Andean foothills of Colombia dictated by altered circumstances and opportunities. The circumstances were the declining supply of water to the community due to deforestation provoked by extension of cattle grazing. The opportunities were: (I) the use of multi-purpose trees (for feed, fuel and soil fertility enhancement); (ii) high yielding biomass crops (sugar cane) providing feed and soil improvement; (iii) recycling of household waste water and livestock manure to produce fuel (biogas) and fertilizer (the effluent); (iv) use of earthworms to convert livestock manure into protein for chickens and organic fertilizer; (v) associated (multi-strata) cropping of horticultural plants with multi-purpose trees to increase biomass yield and enhance biodiversity; and (vi) simplification of the feeding system (giving whole sugar cane stalk and tree leaves to pigs during pregnancy).

Interim results are given showing effects on biomass yield and on soil fertility.

KEY WORDS: Livestock, integration, feed, tree, sugarcane, recycling, biogas, soil fertility

Background

This paper describes some of the results from the introduction of integrated farming systems in a small community (municipalities of La Union and El Dovio) located in the Andean foothills, 1,700m above sea level, in the north of the Cauca Valley in Colombia. The rainfall is 1,400mm and mean temperatures range from 24 C during the day to 14 C at night. The terrain is sloping (>25) and mean daily hours of sunshine are 2.7.

Most of the farm families are of peasant (campesino) origin and own less than 15ha. Traditionally the region was dedicated to monocultural coffee with some fruit trees and vegetables.

The farming systems are now highly diversified as will be described in this paper. Income is derived almost exclusively from farm activities.

The first modifications to the traditional system were made in 1987 on the basis of recommendations by advisers of the Federation of Coffee Producers to introduce cattle in order to promote diversification of the traditional coffee monoculture. Faced with the problem of inadequate feed supply, help was sought from the Fondo DRI (Fund for Integrated Rural Development) which in turn approached CIPAV for advice as to appropriate forage crops that could be grown. CIPAV's first recommendations were:

1. Reintroduction of pigs and partial confinement of the cattle to provide manure for a biodigester to supply biogas as alternative to firewood (to decrease pressure on the remaining forest area) and organic fertiliser as alternative to purchased chemicals.

2. To establish sugar cane and forage trees (Chachafruto = *Erythrina edulis* and nacedero = *Trichanthera gigantea*) as feed sources for cattle and pigs through fractionation of the sugar cane into juice (for the pigs) and residual pressed cane stalk and the cane tops for the cattle. The "chachafruto" was chosen as a protein supplement for the cattle and "nacedero" for the pigs on the basis of CIPAV's experience with these trees in similar ecosystems.

3. Preparation of syrup from cane juice using an "earth" oven in the ground.

4. On-farm manufacture of multi-nutritional blocks using the "scums" from syrup manufacture as binder.

5.Installation of a low cost tubular polyethylene biodigester.

6. Purchase of soya bean meal to complement "nacedero" and the cane juice for the pigs.

7. Establishment of earthworm culture to provide protein (for poultry) and organic fertilizer for vegetables and coffee.

The Present Strategy: the Objectives

The introduction of high yielding forage crops (sugar cane and trees) had increased the offer level of feed for the livestock making it possible to diversify further the areas previously in pasture. This diversification was introduced gradually beginning in 1992 with the aim of:

1. Responding to environmental pressures to conserve the water resources, to improve soil fertility, to control erosion, and to increase biodiversity.

2. Integrating more closely crop and animal activities so as to optimize the recycling of nutrients and water.

3. Reducing the energy and economic costs of farm activities.

The following procedures were introduced:

Protecting the Water Source and Increasing the Efficiency of Water Use

The area dedicated to the protection of the water source had decreased because of the extension of pasture. The watershed had to supply the needs of the community of 12 families and the severe deforestation in the region had led to conflicts over the supply of water. The fenced (to prevent cattle grazing) watershed area was extended to facilitate natural regeneration of trees and shrubs. More trees, of multi-purpose use (eg: Bamboo), were planted in this area. Banks of multi-purpose forage trees were introduced to provide the joint function of protection and source of feed, replacing natural pasture which is highly susceptible to erosion in areas with slopes exceeding 30 .

The water originating from household and general farm activities was decontaminated by using it as the diluent for the manure put into the biodigesters and by passing the resulting effluent from the digester along a series of canals for sedimentation of residual solids and growth of water plants.

Increasing Plant Biodiversity

More multi-purpose trees were planted in areas previously dedicated to pasture with the aim of improving soil fertility, controlling erosion, providing feed for the livestock and eventually for construction purposes and sale as timber. Horticultural crops (Zapallo - Cucurbita maxima), fruit trees and shrub forages (Ramie - Boehmeria nivea and mulberry - Morus alba) were introduced into areas previously dedicated to a single specie. Areas of pasture were set aside for natural regeneration of shrubs and trees. The intensification of the recycling process included the growing of different water plants (water hyacinth, azolla and duckweed).

Increasing Animal Biodiversity

Pigs, poultry and fish were added to the farming system complementing the cattle that had been introduced previously.

Improving Soil Fertility

New plantings of forage trees were done as associations ("chachafruto" with "nacedero") not as single species. Areas previously in pasture were allowed to regenerate naturally. The recycling of crop and livestock wastes was intensified. Increasing amounts of leaf litter and fibrous residues became available for direct (in situ) return to the soil or for processing by earth worms.

Simplifying Farm Work

The system of fractionating sugar cane for the pigs was suspended and replaced by direct feeding of the whole sugar cane stalk to breeder pigs in free-range pasture. This had been facilitated by expansion and change of emphasis of the pig enterprise to concentrate on reproduction and sale of weaners rather than fattening. Fully grown pigs are able to chew up to 15-20 kg of cane stalk daily extracting the juice and "spitting" out the fibre. The "chewed" fibre and the pig excreta were allowed to mix naturally and later used as substrate for the earth worms.

Increasing Animal Feed Supply

This came about through the replacement of pasture by multi-purpose trees and the introduction of horticultural and forage crops into areas previously managed as monocultures (eg: the coffee and the protein banks). The increased efficiency of the recycling process was achieved by introducing water plants which in turn became sources of feed for the pigs and poultry.

Increasing the Self Reliance and Participation in Farm Activities of All Family Members

The diversification of the farming system, and the simplification of certain of the sub-systems, increased the labour demand. At the same time it created opportunities for increased participation by women and children in productive (income-generating) activities. The parallel reduction in labour demand in the nearby towns has been an important factor facilitating this process. Traditional coffee farming is highly demanding of labour but in specific seasons coinciding with the harvest of the beans. Labour was traditionally "imported" into the region to satisfy this "transient" need. In contrast, diversified farming offers steady year-round employment for all family members.

The Preliminary Results

An evaluation of inputs and outputs of this farming system on the farm belonging to Tiberio Giraldo in 1993 was made by Espinel (1994). It is not yet possible to assess the effect of the changes described in this paper as these are still in the introductory stage. Results of the recent evaluation of four of the sub-systems are summarized in Tables 1-4.

The data in Table 1 show the high yields of biomass obtained from sugar cane and associations of the two principal multi-purpose trees planted in the farm. The total areas planted with these crops are: sugar cane 2.1 ha and forage trees 0.7 ha.

Table 1: Mean annual yield of fresh biomass from plots planted with associations of trees (*Trichanthera gigantea* and *Erythrina edulis*) (sample areas was 3,500m^2) or sugar cane (sample area 1,248m^2). Data converted to

hectares.

	Trichanthera gigantea/ Erythrina edulis	Sugar cane
Fresh foliage, mt/ha	81.9	104 (88.4+15.6)*
Dead leaves, mt/ha	13.0	14
Total biomass, mt/ha	94.9	118
Stem cuttings, No/ha	40,000	
Fractionation of sugar cane stalk, % fresh basis:		
Juice (for pigs)		45
Syrup (family)		10
Residual pressed cane stalk		45

***Cane stalk + tops**

Table 2: Yield of fresh biomass after 6 months regrowth from plots (3x2m) planted with associations of trees (*Trichanthera gigantea*, *Erythrina edulis* and *Morus alba*), perennial herbaceous species (*Boehmeria nivea*) and food crops (Maize, beans and pumpkin)*

	Plot 1	Plot 2	Plot 3	Plot 4
Fresh forage, kg/100m^2				
T. gigantea	450	350	380	467

E. edulis	17	50	33	140
M. alba	38	-	33	-
*B. nivea***	-	463	-	450
Weeds	66	-	50	-
Maize, beans, pumpkins*				
Total (6 months)	571	863	496	1057
Annual yield, mt/ha***	114	173	99	211

***Not yet harvested **Mean for two harvests (2 month intervals) projected to 6 months *** Projection to one year assuming similar yields in second 6 month period**

The data in Table 2 indicate that it is highly beneficial, at least in terms of total production of biomass, to associate with the "chachafruto" and "nacedero" other horticultural and forage crops. The impact at the level of the livestock has still to be measured.

The fertility of the soil is one of the most important indicators of the sustainability of a farming system. Conventional ways of measuring soil fertility in chemical, physical and biological parameters are time consuming and expensive and require access to sophisticated laboratory equipment. The biological test of soil fertility (by measuring the growth over 20 days of maize planted in samples of soil from the test areas) is simple, inexpensive and quick. It gives no indication of the factors responsible for improvement or decline of soil fertility but it is an extremely useful tool for monitoring the effects of interventions in the farming system. The results from applying this technique in samples of soil taken from the principal sub-systems described in this paper are presented in Table 3.

The order in which the different sub-systems are placed can mostly be predicted on the basis of the importance of return of organic matter and of N-fixation by leguminous species. The poor rating of the "forest" sub-system indicates that the process of soil formation in tropical forests is a slow process and emphasizes the fragile and transitory nature of tropical soils; and that the maintenance and improvement of soil fertility in tropical ecosystems requires constant attention to the basic principles of soil conservation especially the role of organic matter. It is equally apparent that there need be no conflict between biomass yield and sustainability if the appropriate ecosystems are identified and promoted (eg: sugar cane and multi-purpose trees versus pasture).

The soil "bio-test" is also a useful way of showing farmers how particular crops and cropping systems influence soil fertility and provides a basis for adding an "environmental" element into traditional ways of economic assessment of farming systems.

The data in Table 4 are the production parameters for the pig herd since feeding began with whole sugar cane.

Table 3: Biological test of fertility (growth of maize plants in 21 days) of soil taken from cropping areas (0-25cm depth) (3 samples taken from each "crop" area with 4 repetitions from each sample)

	Height, cm	No of leaves
Red soil	5.56	2.35
Forest*	6.33	2.62
Pasture	6.40	2.78
Sugar cane	7.03	2.73
T gigantea	7.92	3.02
E edulis + T	8.49	2.91

gigantea		
Worm compost	9.12	3.20
SE	�0.28	�0.15
Prob	0.001	0.009

***Replanted on eroded red soil**

Table 4: Pig production parameters in Cipres Farm (Oct 95- Sep 96)

Breeding performance:	
Total number of services	29
Number repeat services	4
Percent repeat services	14
Farrowing performance:	
Number of farrowings	21
Average pigs born alive per litter	10.1
Average birth weight, kg	1.2
Farrowing interval, days	176
Weaning performance:	

Number of litters weaned	19
Pig weaned per litter	8.2
Pre-weaning mortality	20.4
Average weaning weight, kg	7.3
Average age at weaning, days	51.3
Population:	
Average female inventory	12
Feeding of sows: Feed per sow, kg/day (fresh basis)	
Sugar cane stalks	10
Soybeans	0.4
Foliage	2
By-products	0.3

Reference

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Outcome of Networking People on Livestock in Crop-based Farming Systems in Asia

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Abstract

Recognizing the importance of animals in smallholder farms, the crop-animal systems research (CASR) in Asia evolved in 1984 out of the IRRI Asian Cropping Systems Network, later renamed Asian Rice Farming Systems Network (ARFSN). Collaborative on-station and on-farm research among 4 countries was initiated on different rice ecosystems primarily to develop appropriate technologies and methodology. By 1994, the number of CASR sites of ARFSN increased from 5 to 72 in 9 countries. In many Asian countries, the crop-animal systems research has been institutionalized in the national research programs and expanded to non-rice crop systems.

The conduct of CASR requires an interdisciplinary team from the biological, social, economic, environmental disciplines immersed in on-farm situation. Differences in research and extension organizational structure, availability of interdisciplinary scientists, and financial support hinders the implementation of systems research involving animals. AFRSN provided a venue for animal scientists to reorient research towards increased animal productivity in small farms, to work closely with crop scientists, sociologists and economists, and to appreciate the farmers' priorities in resource allocation. Towards this end, a working group was organized to link researchers, extension workers and policy makers. Thus, the farming systems research methodology, involving diagnosis, design,

evaluation and technology transfer, was modified by the different national research teams appropriate for a given ecosystem.

Some highlights of CASR project results are presented and discussed. More importantly, the following issues need to be addressed:

1) refinement of the economic and environmental impact assessment of crop-animal technologies;

2) testing the validity of CASR under a large-scale production system, i.e. pilot production program;

3) the ability to anticipate the broad socioeconomic ramifications of fast economic development in Asia and its effects on crop-animal integration in small farms.

KEY WORDS: network, crop livestock integration, research and extension methodology, Asia, rice, smallholder farm, on-farm research, feed, residues, by-product

Introduction

Animal production systems in Asia are generally an integral part of crop production. Farmers' production systems are complex and vary depending on the physical, biological and socio-economic environments. Farmers consistently diversify the use of their resources as there are interactions of various activities, not only within the crop and animal components, but also between them and the other enterprises or activities on the farm and off-farm. Furthermore, Asian farmers own small areas of land from less than 0.5 ha in China to about 5 ha in Thailand and Myanmar. A typical farm in Asia consists of a cropping area, and a homestead with the house, trees, vegetables and animals.

The most economically important animals are cattle, buffalo, goats, sheep, chickens, ducks and pigs. Animal production systems can be classified into three broad categories: smallholder, semi-intensive and intensive. The dominant production system is the smallholder. Most farmers raise combinations of different animals depending on

their farm size, available labour, socio-economic conditions, cropping intensity, soil type, rainfall etc.

Cattle and water buffalo are raised mainly for cash, draught, meat, milk, as a source of manure for the crops, fuel, transportation, utilization of crop residues, and other related purposes. Goats and sheep are important components of farming especially in Indonesia, India, Nepal, Philippines and China. They are raised for cash, food, security, prestige and social values, and for the utilization of by-products. In West Java for example, one in every 5 farmers raises sheep and goats which contributes 14% and 17% of the income in the lowlands and uplands, respectively.

While the commercial pig and chicken farms are well developed due to the application of advanced technologies in breeding, nutrition, farm management and disease control, more than 80% of these animals are still raised in the "backyard". Approximately 90% of smallholder farmers raise chickens for food (meat and eggs), cash, utilization of by-products and for manure.

The Need for A Novel Research Approach

To improve animal production in smallholder farming systems, a change in approach was needed to solving the problems of animal production affecting the small farms in Asia. The traditional discipline-oriented research in animal science had resulted in the development of many animal production technologies. However, the impact of these has been more towards increasing productivity in commercial animal systems rather than that of animals in smallholder farms. Apparently, there was a need to reorientate animal research activities in Asia to focus more on the problems and constraints to animal production in small farms. There was a need for animal scientists to work closely not only with crop scientists, but more with farmers who are concerned foremost with crop production. An appreciation by animal scientists of how crop-based farmers allocate their limited resources to either crops or animals and of on-farm constraints to the application of matured technologies was necessary to be able to design and implement on-farm research with systems perspective.

Thus, the Asian Rice Farming Systems Network (ARFSN) conducted a series of meetings among scientists working on different commodities and disciplines, and research managers from national agricultural research stations

(NARS) to develop a methodology for systems research. Initially, the methodology was for rice-based farms, but this was expanded to other crops by the collaborating countries according to their dominant agro-ecosystem. Eventually, a crop-animal systems research methodology was developed. The research methodology continuously underwent refinement depending on the needs and resources in a given environment.

Crop-animal Farming Systems Research in Asia

The evolution of the crop-animal systems research in Asia can be traced back from 1974 with the establishment of the Asian Cropping Systems Network at the International Rice Research Institute (IRRI). The network was established to facilitate collaborative research between IRRI and the national research system in selected Asian countries with the aim of increasing productivity and income from rice and non-rice crops in different rice environments. The research teams then were mainly composed of agronomists, soil scientists and economists doing on-farm, researcher-managed experiments with minimal farmer-participation.

In the early 1980's, research objective shifted to maximizing farm income particularly in the rainfed rice environment, where the farmers are involved in a more complex farming system which includes non-rice crops, animals and trees. The interdependence of rice with the other economic commodities in terms of resource allocation resulted in the expansion of the activities of the network. Towards the late 1980's, the issue of family welfare of Asian farmers was likewise recognized. Thus, the pool of researchers in the network was expanded to include animal scientists, veterinarians, sociologists and anthropologists. The network was later renamed Asian Rice Farming Systems Network to cater for all the research needs of the whole farm.

Due to the strong interaction among the physical, biological and economic environment, a systems approach to research was taken into consideration in the development of technologies that are likewise consistent with the farmers' goals and needs. Farmers' experience, indigenous knowledge and current practices were considered in the design of on-farm experiments and backed up by on-station research.

The early 1990's was ushered in with the need to sustain the natural resource base. This necessitated better

complementarity between crops and animals to enhance family welfare, address equity issues and the like. Towards this end, on-farm crop-animal research was conducted with strong farmer participation based on a farming systems perspective. Four key research sites in four countries were established for the understanding of crop-animal systems and for the development of a research methodology.

The Research Methodology

Although modified by different countries, the basic components of the research methodology for crop-animal systems were the same. The steps followed were:

(1) selection of target area and research site;

(2) diagnostic/site description;

(3) design of component and system technologies

(4) testing in farmer's fields with the participation by farmers;

(5) extension of promising technologies in collaboration with extension workers.

The following are the key features of the approach: involvement of farmers in the research process; multi-disciplinary and inter-commodity research cum extension; environmentally-oriented; consideration of farmers' resources in the design of experiments; decentralized research; focused on increasing production and profitability; and a feedback mechanism between field and discipline researchers to make on-station research more relevant to farmer needs.

The description/diagnosis of the research site consists of a survey to identify the existing systems, the physical, biological and socio-economic characteristics, crop-animal interactions, and production constraints. The rapid rural appraisal method was adopted by most national programs. While the data gathered were more qualitative, it served

the purpose of understanding the production systems practised by farmers, identifying the constraints and exposing scientists to real farm conditions. However, where extrapolation of research results to other areas was needed, more quantitative data were gathered.

Based on the problems and the environmental characteristics of the site and in consultation with the farmers, experiments were drawn by a multi-disciplinary team. In many cases, technologies developed on research stations were used as an intervention to existing farmers' practice, with or without modifications based on consultation with the farmer- cooperators. Due to constant monitoring of the experiments by both the researchers and the farmers, refinement of the research protocol was made possible even in the middle of the study.

Simultaneously with the development and refinement of the on-farm research methodology on crop-animal systems, several training programs, workshops and meetings for farming systems practitioners were conducted from 1987 to 1995, with ARFSN either as sponsor or as collaborator. Since 1972, more than 500 researchers took FSR and FSR-related courses at IRRI. This was augmented by similar national training programs in different countries. Most of the participants were crop scientists and very few were animal and social scientists.

The workshops and meetings were convened to provide a forum for the presentation of project progress reports and exchange of information among the members of the Network and other international research institutions.

Research Collaboration on Crop-animal Systems

The most important problems in animal production are the lack of nutritious feeds particularly during the dry season and the consequent low productivity of the animals. Farmers generally feed their animals with residues and by-products of rice, corn, wheat, soya beans, mung bean and groundnuts. To increase the utilization of crop by-products as animal feeds, two major research activities were conducted through the Asian Rice Farming Systems Network. These are on-station research and on-farm research. On-station research focussed on assessing the nutritional quality of forage crops and formulating rations which included home-grown feeds. On- station research identified and recommended forage crops that could increase the daily weight gain of ruminant animals. However,

on-farm research had to be conducted to fit the recommended forage crops into farmers' cropping systems.

On-farm research was conducted at key sites representing specific rice ecosystems where farmers traditionally have an integrated crop and animals systems. The following are the outcomes of the on-farm research conducted at some of the key farming systems research sites. These sites have different combinations of crops and animals in specific rice ecosystems.

1. Zhenjiang, Hangsu, China (Irrigated)

Research at this site focussed on improving farmers' cropping patterns to supply quality feeds for swine and introducing improved breeds of swine. In the uplands, wheat or barley followed by soya bean or groundnut are grown, while wheat or barley-rice and rapeseed-rice are the common cropping patterns adopted in the lowlands. Soya bean and rapeseed cakes are used as feeds for pigs. However, the higher rice fields suffer from drought, and thus maize was tested to replace rice. In the lower fields improved varieties and agronomic practices for wheat-rice and rapeseed-rice were introduced. New cropping patterns were evaluated in the upper rice fields consisting of wheat or barley-maize, rapeseed-maize and barley-maize+soya bean. Yield of maize was 10% higher than rice and income from maize stover (sold to the dairy farm as silage) was 50% higher than rice straw. The total net income of rice and maize were the same. With the advantages of maize as animal fodder, farmers increased the area of maize from 0 to 1300 hectares in 1990.

The performance of hybrid pigs (Yorkshire x Taihu) was compared with the local breed, while the traditional system of feeding was compared with improved mixed feeds. Results showed that improved breeds fed with mixed feeds produced a higher net income, more efficient feed conversion and shorter feeding duration. This project was conducted by the Chinese Academy of Agricultural Sciences.

2. Changping, Beijing, China (Partially Irrigated)

Changping county is one of the main dairy production areas in Beijing, contributing one fourth of municipal milk production. Wheat-maize, wheat-maize (silage) and monocrop rice (transplanted and dry-seeded) are the farmers'

dominant cropping patterns in irrigated upland and lowland fields. In rainfed, upland, monocrop maize is commonly adopted. Dairying is either managed by the state or cooperatives. The major constraint on dairy production was the short supply of maize and sorghum from irrigated upland fields for silage making. In the paddy fields, 60-70% were still monocrop rice and some farmers grew rice-wheat and barley silage-rice. The yield of barley was low, about 2.25t/ha. Cropping intensity in the uplands was already at a high of 200%, thus there was little potential for increasing silage production in those areas. The only way to increase silage production was to introduce silage crops during the winter- spring period after monocrop rice. In 1986, ARFSN launched a project to introduce triticale for silage production. Yields under irrigation at Yantan Township were very high (50 t/ha), resulting in a net income from the system of US$1,421, which was 114% more that for single-cropped rice and 44% more than for wheat-rice.

Results of a feeding trial conducted in Baifong village showed that there was no significant difference in milk production between cows fed on maize silage and those fed on triticale silage. The nutritive value of triticale even appeared superior, thus increasing crude protein and fat contents in the milk. Lactose percentage remained the same.

In 1988, the results of the feeding trial attracted the attention of the Beijing Municipal Bureau of State Dairy Farming Management, which organized a visit to the research site for dairy farm officials and farmers. The bureau decided to introduce triticale into its many dairy farms throughout the Beijing region. It was not only adopted in a triticale (silage)-rice pattern in the lowlands but also in triticale (silage)-maize (silage) pattern in the uplands. By 1993, the area devoted to triticale was about 2,600 ha or more than 60% of the total area devoted to winter silage crops. Average yields were 32 t/ha, while net incomes were US$207/ha, US$131 higher than from barley. Triticale was introduced and tested in another 15 provinces/municipalities in northwest China, central China and south China. The acreage outside Beijing was about 223.4 ha. The research had led to the reorientation of China's breeding programme of triticale for human food to silage use as well. The Chinese Academy of Agricultural Sciences (CAAS) has recently released several new varieties for silage production.

3. Batumarta, South Sumatra, Indonesia (Rainfed, Upland)

Several models (combinations of crop and animals) were evaluated with the main objective of increasing farmers income to a minimum income of $1,500/year. The models were:

a) FSA - farmer's system without animal;

b) FSB - farmer's system with livestock;

c) FSC - gradual improvement with livestock;

d) FSD - introduced improvement with livestock.

FSA and FSB were existing farmers' practice; FSC had one cow, 3 goats and 11 chickens and FSD had 2 cattle, 5 goats and 23 chickens. Five farmers from each system were involved and were selected from those who adopted the improved cropping patterns. Farmers adopted the cropping patterns which included maize, upland rice, cassava and legumes such as groundnut and cowpea, grown in a relay intercrop system. After three years of on-farm testing, households adopting the models FSC and FSD achieved the minimum income target of $1500/family/year. With these promising results, FSC was evaluated in six village units involving five farmers in each village, with a total of 30 household cooperators. Farmers were carefully selected from farmer groups organized in each village and were given short training courses on the technology of the crop-animal system with emphasis on the technologies for FSC. Each household cooperator received credit for food production, 3 goats and 11 chickens. All of these households already owned cattle. Credit was provided by the project through the village unit cooperative. The payment of farmer cooperators became a revolving fund and extended to other members of the farmer group who were not involved in this project.

Within 3 years the population of cattle, goats and chickens increased. After six years of testing involving many farmers, the FSC was compared with farmers' existing systems without animals. The net income of FSC was 67% higher compared with the farmers' existing farming systems (without animals).

4. Santa Barbara, Pangasinan, Philippines

The research project was conducted in the rainfed village of Carosucan, Santa Barbara, Pangasinan, where farmers grow only one rice crop a year, leaving the land fallow after harvest. To increase cropping intensity, different cropping patterns were tested for three years. Rice followed by cowpea and mung beans were the most promising cropping patterns. After 2 years, 67% of the farmers planted mung bean and more than 90% in 1993. Net income increased from 80 to 155% more than that of farms with a monocrop of rice. Forage legumes are important components of the diet of ruminants especially for improving the utilization of fibrous residues like rice straw and for green manuring. Hence production of forage legumes in rainfed lowland areas is a strategic approach in the development of a year-round feeding system for ruminants. Scientists and farmers tested three forage crops - siratro, sunn hemp and Desmanthus. Among these forage crops, siratro proved the ideal companion for mungbean. Siratro provided four clippings for feeding to cattle, each with a yield of 3 t/ha, and a further 2.5 to 3.5 tons from the last regrowth, which was used as green manure for the following rice crop. The Bureau of Agricultural Research in Manila is now testing the improved rice-mung bean + siratro system in other provinces. Each province sent two representatives to a 2-week training course held at the Department of Agriculture to introduce the system. The main impediment to more widespread adoption is the shortage of siratro seed.

5. Ban Phai, Khon Kaen, Thailand

In Ban Phai, Khon Kaen, Thailand, the traditional cropping system was monocrop rice in the lowlands and cassava in the uplands. To improve the quality of feeds and utilize crop byproducts and residues, several crops such as corn, mung beans, cowpea, groundnuts were evaluated in the uplands and upper paddy areas. Artificial insemination was introduced to produce half-bred cows from American Brahman and Holstein-Friesian for dairying and the male for beef production. Backyard forage production using stylo, napier and ruzi grass were evaluated for night feeding and urea-treated straw was also introduced. Net cash income of the animal-based farmers was 100% more than the crop-animal based and 207% more than the crop-based. In all groups, the income from animal production was higher. Farmers at all experimental sites, including the neighboring villages, adopted the production of ruzi grass in bigger plots close to their homesteads.

Lessons Learned From Crop-animal Collaborative Research

The organization of the crop-animal systems research network was a learning experience. The complexity of different farming systems, diversity of production systems and the socio-economic constraints of rice-based farming households provided challenges to researchers and extension workers. The following were the lessons learned from the research network:

1. Organizational Difficulty

The methodology for crop-animal farming systems research required multi-disciplinary teams of social scientists, animal nutritionists, agronomists, livestock specialists, veterinarian, etc. However, these specialists come from different offices, ministries and departments. Thus, it was difficult for these specialists to coordinate their work and moreover to conduct field visits especially if the research sites are remote. There is generally a lack of social scientists, including economists, who have the interest and time to work with the other disciplines at the farm level. However, there are exceptional cases in Thailand, Indonesia and the Philippines where social scientists from agricultural universities worked together with scientists from farming systems research institutes.

2. Methodological Problems

Since the evaluation of systems and component technologies managed by farmers was replicated across farms, the variability of results was generally high, resulting in statistically insignificant differences. While more replicates are ideal, the conduct of research becomes more difficult and expensive. Occasionally, the farmers assigned to the control group duplicated some of the recommended practices. Similarly, there was tendency for some researchers to dictate to the farmers the experimental interventions rather than involving farmers in all phases of research particularly in getting their feedback.

3. Research Emphasis

There was more emphasis on nutrition and forage research and less on the different aspects of animal production. This is expected since the lack of forage for ruminants and high cost of concentrates for monogastric animals are the dominant problems under Asian conditions. Furthermore, crop by-product utilization by ruminants is the major

point of crop-animal integration.

4. Socio-economic Constraints

In spite of the availability of crop-animal technologies developed, tested and evaluated on the research station and at the farm level, the adoption rate is low due to several socio-economic constraints (Paris *et al*.,1995). These are:

a) Farm labour shortage due to the higher off-farm wages and greater opportunity costs of family labour (especially males);

b) Unfavourable government agricultural policies which provide disincentives for small livestock development;

c) Unavailability of required inputs and support services;

d) Risk aversion and perceptions of technology by farmers;

e) Inadequate training and extension for technologies which require knowledge and information;

f) Lack of credit to the poor without collateral. For example, the dairy industry in Thailand prospered due to incentives and support which the Thai government gave at the community and farm level. Farmers were encouraged to specialize in forage seed production. In the Philippines, farmer cooperatives supported by the Land Bank provided credit not only for rice inputs but also for procuring large and small animals.

5. Farmer Participation

While farmer participation was very much emphasized in the methodology of crop-animal on-farm research, very few trials have included women farmers who play crucial roles in large and small animal production. It is now realized that they will play even greater roles in the management of farm animals and in sustaining household food security due to the increasing male migration to the cities. More efforts are now being undertaken to recognize women's roles in crop and animal production and in including them in research and extension activities.

Conclusion

ARFSN, as its major contribution to agricultural research in Asia, has exposed and trained local scientists in the conduct of on-farm animal research. As such, it has instilled into the researchers the need for collaborative research not only among institutions but, more importantly, with the farmers. With the current concern for sustainable agriculture amid dwindling funds for tropical agriculture research, ARFSN has put in place a critical mass of human resource with skills and capabilities to pursue research based on farmers' needs and aspirations. Provided with support by their respective national research programs, this pool of scientists can largely contribute to the improvement of rural life in Asia through appropriate research approach.

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Information on Livestock Feed Resources and Integrated Farming Systems from the Electronic Journal Livestock Research for Rural Development

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Abstract

Livestock Research for Rural Development was the first scientific journal to be published only in electronic form, firstly on diskette and subsequently via ftp (file-transfer-protocol) and over the World-Wide-Web. The objective was to both publish information and make it available to scientists in developing countries, who had difficulty in the past due to the high costs of conventional publishing. It was started in 1989 and 20 issues (200 papers) have been distributed to over 600 persons in more that 40 countries. There are no restrictions on copying and onward-distribution so a far greater number of readers probably exist.

The focus has been on nutrition and management within systems appropriate to the tropics. There have been articles on most livestock species, including buffalo, goats, sheep, pigs, ducks and poultry, as well as cattle; and many tropical feeds, but particularly sugarcane and its by-products, legume trees, palms, water plants and other unconventional resources. These have included more detailed aspects such as chemical treatment, mineral supplementation and anti-nutritional factors. Several papers have been included on systems methodology and the development process.

KEY WORDS: Electronic journal, livestock research, rural development, tropical feeds, unconventional feed resources

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Background

Research on feed resources, and particularly journals where such information is published, are still monopolised by institutions in the industrial countries situated in temperate latitudes. There is a great need to expand research on feeds and feeding systems appropriate to tropical environments, and to promote means for dissemination of the information which can be a major stimulus for doing the research in the first place.

It is now well recognized that research and scientific publications in temperate developed countries have little relevance to the problems facing researchers and farmers in tropical developing countries. Furthermore, in most tropical developing countries laboratory analytical facilities are poor and expensive to develop and maintain. It is not surprising therefore that many of the techniques used to assess feeds in temperate countries are not applicable in the tropics.

The need is not for a set of "tropical feeding standards" but for information about the nature of tropical feed resources and how they are used by animals. Such information is being gathered by research workers in developing countries, many of whom are funded by the innovative support organization, IFS (the International Foundation for Science*). Indigenous knowledge, handed down from farmer to farmer, is also one of the most appropriate sources

of such information. The problems are, firstly, to document this knowledge and secondly to disseminate it widely among potential users. Many of the researchers are turning to on-farm research where they can fulfill these objectives more effectively than in laboratories or research stations.

A first effort to provide a vehicle devoted to more appropriate tropical studies was achieved with the publication of the journal Tropical Animal Production from 1976 to 1982. Some years later, the electronic journal Livestock Research for Rural Development was established in 1989 in the belief that conventional methods of publishing scientific information were too expensive, not appropriate and not sustainable in the context of developing countries. The concept is more fully documented in the original paper by Preston and Speedy (1989). There were two principal objectives:

1. To offer an alternative forum to "young" scientists in tropical developing countries for the exchange of scientific information;

2. To utilize electronic information technology to minimize costs of preparation and distribution.

Over the 8 years of its existence there have been minor changes in style in response to the opportunities presented by developments in computer technology and data exchange, especially the growth of the Internet and the Word-Wide-Web. But the basic principles have been maintained of offering a forum to scientists in tropical developing countries combining minimal cost, easy access and rapid publication of appropriate information.

Information on Livestock Feed Resources and Integrated Farming Systems

The focus has been on nutrition and management within systems appropriate to the tropics. For example, *the following articles reported studies on small farming systems*:
Effect of supplements of balanced concentrates and cottonseed cake on milk production in Mauritian villages (Boodoo A A *et al*., 1990)
Suggestions for intensive livestock-based smallholder systems in semi-arid areas of Tanzania (Ogle B, 1990)

Economia campesina y uso de los recursos naturales en zonas de colonizacion (Rojas H, 1990)
Role of women in homestead of small farm category in an area of Jessore, Bangladesh (Paul D C and Saadullah M, 1991)
Goat production in south-west region of Bangladesh (Paul D C, Haque M F and Alam M S, 1991)
Technology and competitiveness of small dairy farms in Costa Rica (Holmann F *et al*., 1992)
Smallholder milk production, milk handling and utilization: A case study from the Nharira / Lancashire farming area, Zimbabwe (A N Mutukumira, D M J Dube, E G Mupunga and S B Feresu, 1996)

***Papers relating to specific alternative feeds used for different types of livestock include*:**
Utilizacion de la cachaza de palma africana como fuente de energia en el levante, desarrollo y ceba de cerdos (Ocampo A *et al*., 1990)
Azolla filiculoides as replacement for traditional protein supplements in diets for growing-fattening pigs (Becerra M *et al*., 1990)
Utilizacion de jugo de cana y cachaza panelera en la alimentacion de cerdos (Sarria P, Solano A and Preston T R, 1990)
"A" molasses in diets for growing ducks (Men B X and Su V V, 1990)
Effects of substituting dolichos bean meal with soya bean meal on the performance of broiler chicken (Sarwatt S V *et al*., 1991)
A comparison of sugar cane juice and maize as energy sources in diets for growing pigs (Speedy A W *et al*., 1991)
Multi-Nutrient Blocks as supplement for milking cows fed forages of low nutritive value in South Vietnam (An B X *et al*., 1991)
Utilizacion de follaje de Nacedero (Trichantera gigantea) en la alimentacion de cerdos de engorde (Sarria P *et al*., 1991)
Molasses-urea block (MUB) and Acacia mangium as supplements for crossbred heifers fed poor quality forages (Bui An X *et al*., 1992)
Effect of Leucaena leucocephala and Brassica napus on growth of pigs fed wheat bran diets (Muir J P *et al*., 1992)
Ammoniated rice straw or untreated straw supplemented with a molasses-urea block for Sindhi x local cattle (Bui

Van Chinh *et al*., 1992)
Feeding ensiled poultry excreta to ruminant animals in Syria (Hadjipanayiotou M *et al*., 1993)
Evaluation of Sapindus saponaria as a defaunating agent and its effects on different ruminal digestion parameters (Diaz *et al*., 1993)
The use of sugar cane juice and molasses in the diet of growing pigs (Bui Huy Nhu Phuc, 1993)
Efecto de tres forrajes arboreos sobre el consumo voluntario y algunos par metros ruminales en ovejas africanas (Vargas J E, 1993)
Laboratory evaluation of ensiled olive cake, tomato pulp and poultry litter (Hadjipanayiotou M, 1994)
Study on the use of algae as a substitute for oil cake for growing calves (Chowdhury S A *et al*., 1994)
Fattening pigs with the juice of the sugar palm tree (Borassus flabellifer) (Khieu Borin, T R Preston and B Ogle, 1995)
Duckweed - a potential high-protein feed resource for domestic animals and fish (Leng R A, Stambolie J H and Bell R, 1995)
Effect of protein supply in cassava root meal based diets on the performance of growing-finishing pigs (Liliana Ospina, T R Preston and B Ogle, 1995)
Lombriz roja Californiana y Azolla-anabaena como sustituto de la proteina convencional en dietas para pollos de engorde (Lylian Rodriguez, Patricia Salazar y Maria Fernanda Arango, 1995)
The forage tree Erythrina fusca as a protein supplement for cattle and as a component of an agroforestry system (Piedad Cuellar, Lylian Rodriguez and T R Preston, 1996)

There is a very valuable paper on the different types of forage trees used in Tanzania:
Indigenous knowledge in utilization of local trees and shrubs for sustainable livestock production (Komwihangilo D M *et al*., 1994)

Papers on research and development methodology have also been given:
Adding a learning to a blueprint approach - or what a small amount of flexible money can do. (Dolberg F, 1991)
Integration of livestock with agro-climatic zone-based land use planning (Gupta A, 1992)
Studies on the knowledge of rural women regarding local feed resources and feeding systems developed for

livestock (Rangnekar S D, 1994)
Research, Extension and Training for Sustainable Farming Systems in the Tropics (T R Preston, 1995)

These are intended as examples of the type of studies reported. The full references are given at the end of this paper. A comprehensive list of the contents to date can be obtained by sending an e-mail message to the conference coordinators.

Availability

Livestock Research for Rural Development is now available in three formats:

- **The MS-DOS format**
- **The Windows.hlp format**
- **The Adobe Acrobat.pdf format**

The MS-DOS Format:

This is the normal DOS version that has been the standard format up to the present and which runs from the DOS Prompt by typing "J". It is appreciated that not all readers have access to 486 and higher processors and that this "stand alone" version of the journal continues to fulfill an important role. It will continue to be produced in the CIPAV office in Colombia and distributed to those contributers who wish to receive LRRD in the MS-DOS format. For those readers who have an InterNet connection, the MS-DOS version can be down-loaded by "FTP" from:

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The Windows .HLP Format:

This new Windows version is based on the Windows Help system (run with WINHELP.EXE). This works just like any Windows Help file and needs no special instructions. For those readers who have an InterNet connection, the new Windows Help version can be down-loaded by "FTP" from:

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The Acrobat .PDF Format:

This version of LRRD maintains the precise format of the original paper as prepared by the Word Professing Software (in this case WordPerfect 6.1 for Windows). The advantage is that it is much easier to prepare than the DOS or Windows Help versions. It has excellent search and "hypertext" capabilities that facilitate moving from contents to papers and back again etc. The disadvantage is that you need the specific software "Acrobat Reader" to be able run it. The Acrobat Reader can be downloaded "free" from the InterNet; also it (the reader) will occupy about 1Mb of space on your hard disk.

The "Acrobat" version is available for LRRD 7.2 onwards. The "Acrobat" version for 7.2 onwards as well as previous MS-DOS versions are available on the World Wide Web at:

http://ifs.plants.ox.ac.uk/lrrd/lrrd.htm

For readers resident in Vietnam these versions of the journal are available on the "VIETNET" List Server located at the University of Agriculture and Forestry in Ho Chi Mi City. Researchers in developing countries are encouraged to establish national networks such as VIETNET as a means to facilitate the distribution of LRRD from the editor to a server in each country to which each national researcher may have access for retrieving the last issues. Obviously, this server may also be used for providing others sources of information.

For the last 2 years, the publication of LRRD has been supported by FAO through its regional network on Feed Resources in Latin America and the Caribbean funded by France.

Submission of Papers

Papers are submitted on disk (either 3.5 or 5.25inch) in WordPerfect or similar format, to the regional language sub-editor. The paper can be in any of the official languages: Spanish, Portuguese, French and English, but the preferred format should be followed.

Authors are required to have their papers refereed, before submission, by at least two scientists who have both postgraduate qualifications and proven experience. A signed statement by the referees should accompany the submission. When authors have difficulty in locating appropriate referees, they should contact the nearest sub-editor who will provide names of suitable candidates.

Full details of how to submit and the Notes for Authors are given in the latest issue of the journal.

***Further details can be obtained from*:**

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The Role of Scavenging Poultry in Integrated Farming Systems in Ethiopia

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Abstract

This paper focuses on the role of scavenging poultry in integrated farming systems and is mainly based on previous studies and past research and development attempts to improve scavenging poultry in Ethiopia. Village poultry production is an integral part of a balanced farming system and has a unique position in the rural household economy, supplying high quality protein to the family. In this paper, the present structure, socio-economic aspects, constraints, potential and future prospects of scavenging poultry in the mixed farming systems are described, and recommendations are also made to change the present scavenging system to semi-scavenging system.

KEY WORDS: Poultry, scavenging, semi-scavenging, village, Ethiopia, mixed farming system

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Introduction

Rural poultry production in Ethiopia represents a significant part of the national economy in general and the rural economy in particular, and contributes 98.5 and 99.2% of the national egg and poultry meat production,

respectively (AACMC, 1984), with an annual output of 72,300 metric tonnes of meat and 78,000 metric tonnes of eggs (ILCA, 1993).

Comparatively little research and development work has been carried out on village poultry, despite the fact that they are more numerous than commercial chickens, accounting for around 99% of the total number in the country. Studies carried out at the College of Agriculture, Alemaya (Bigbee, 1965) and Wolita Agricultural Development Unit (WADU) (Kidane, 1980) and by the Ministry of Agriculture (1980) indicated that average annual egg production of the native chicken was 30-60 eggs under village conditions and that this could be improved to 80-100 eggs on-station.

A recent study at Asela Livestock Farm revealed that the average production of local birds around Arsi was 34 eggs/hen/year, with an average egg weight of 38 g (Brannang and Persson, 1990). These results look unimpressive when compared with egg-laying exotic breeds which can produce more than 250 eggs/hen/year, with an average egg weight of 60 g. They show that local birds are poor producers of small sized eggs. But smallholder poultry production using unimproved stock can be the most appropriate system in practice, with low input levels that makes the best use of locally available resources. Village poultry are important providers of eggs and meat as well as being valued in the religious and cultural life of society in general and the rural people in particular.

As pointed out by Sonaiya (1990), in recent years, rural poultry have assumed a much greater role as suppliers of animal protein for both rural and urban dwellers. This is because of the recurrent droughts, disease outbreaks (rinderpest and trypanosomiasis) and decreased grazing land, which have resulted in significantly reduced supplies of meat from cattle, sheep and goats. Poultry is the only affordable species to be slaughtered at home by resource-poor farmers, as the prices of other species are too high, and have increased substantially in recent years. Consumption of pork is not allowed for religious reasons for most Ethiopians (Orthodox Christians and Muslims) but fortunately there are no such cultural or religious taboos in relation to the consumption of poultry and poultry products.

Ten years ago, per capita consumption was about 57 eggs and about 2.85 kg of chicken meat per annum in Ethiopia

(Alemu, 1987), which are very low figures by international standards. Although there are no current data on the present per capita consumption of poultry products, a similar or even declining trend is probable because the population of Ethiopia has increased by about 3% per annum over the last ten years without any marked increase in the production of poultry meat and eggs. Innovative ideas and programmes are therefore required to promote rural poultry production for the improvement of rural household incomes and nutrition.

Poultry production is an effective means of transferring wealth from the high-income urban consumers to the poor rural and peri-urban members of the community. Small scale poultry development should therefore concentrate on the rural and peri-urban areas of the country. The focus of this study was on villages in the central highlands of Ethiopia.

Present Structure of Poultry Production in Ethiopia

The total poultry population in Ethiopia is estimated to be 56.5 million (ILCA, 1993). Poultry production systems in Ethiopia show a clear distinction between traditional, low input systems on the one hand and modern production systems using relatively advanced technology on the other (Alemu, 1995). Ninety-nine per cent of the population consists of local breed types under individual farm household management (Alamargot, 1987), and the remaining 1% of birds are mainly in state-run modern production systems, with a very small proportion in private units. Of the total national egg and poultry meat production 98.5 and 99.2% respectively are contributed by local birds (AACMC, 1984), resulting in an annual output of 72,300 metric tonnes of poultry meat and 78,000 metric tonnes of eggs.

Large-scale Commercial Systems

Modern poultry production started in Ethiopia about 30 years ago, mainly in colleges and on research stations. The activities of these institutions mainly focused on the introduction of exotic breeds to the country and the distribution of these breeds to farmers, including management, feeding, housing and health care packages.

The history of poultry production in the industrialized countries may offer some basic knowledge and guidelines for

poultry development in the developing countries as a whole and in Ethiopia in particular, but in view of the particular conditions in different countries and regions, specific research and development approaches are needed to determine which are the optimum production systems and development strategies.

Most of the research work is still being carried out on intensive poultry production, with modern housing and sophisticated feeding systems. However, the great majority of poultry production is based on extensive rural production systems where the results of current research are often not applicable.

Today, a number of large commercial state farms have been established and private poultry farms are starting to operate in the country. This would seem to be a positive trend in increasing the supply of animal protein for the Ethiopian people, whose primary source of protein is of plant origin, because poultry are efficient converters of by-products and grains into eggs and meat, and have a fast turnover and rapid growth rate. In spite of these advantages, including intensive poultry production in the livestock development strategy must be questioned, due to the fact that commercial poultry compete with human beings for scarce food grains. This statement is justified if we consider the composition of diets used on the industrial poultry farms, where the major ingredients are high quality cereals like maize and wheat (AACMC, 1984).

If we consider commercial poultry production under Ethiopian conditions, where there is a national shortage of grain to feed an ever-increasing human population and a negative trade balance, then allocating hard currency to import breeding stock, medicines, vitamin-mineral pre-mixes and concentrates to support intensive poultry farms will involve critical political as well as economic decisions. So, in a country like Ethiopia, the outcome will be the converting of food that resource-poor people can usually afford to buy, to smaller amounts of luxury food items that only the minority wealthy members of the society can afford.

No attempts have been recorded to evaluate the performance of exotic birds under local farmer conditions. The only serious on-station attempt carried out in Ethiopia was a comparative study of the performance of six different exotic breeds, namely: Brown Leghorn, White Leghorn, Rhode Island Red, New Hampshire, Light Sussex and Barred Rock at Debre Zeit Agricultural Research Centre. This study showed that the White Leghorn was the best

performing exotic layer breed (DZARC, 1984).

Rural Poultry Production Systems

There is no generally accepted definition of rural poultry production, and various production systems have been described by a number of authors, including Huchzermeyer (1967), Aini (1990), Cumming (1992), Alemu (1995) and Tadelle and Ogle (1996a). The production systems are characterized as including small flocks, with nil or minimal inputs, low outputs and periodic devastation of the flocks by disease. Birds are owned by individual households and are maintained under a scavenging system, with little or no inputs for housing, feeding or health care. Typically the flocks are small in number with each flock containing birds from each age group, with an average of 7-10 mature birds per household, consisting of 2-4 adult hens, a male bird and a number of growers of various ages. Tadelle and Ogle (1996a), Gunaratne *et al*.,. (1992) and Cumming (1992) also described village poultry flocks in Asia as including 10-20 birds of different ages per household. According to AACMC (1984), in Ethiopia there is an average of six indigenous birds per household and, according to Sonaiya (1990), the average flock size in Africa ranges from 5-10 birds. As described by Tadelle and Ogle (1996a), the village poultry production system is characterised by minimum inputs, with birds scavenging in the backyard, and no investments beyond the cost of the foundation stock, a handful of grain each day and possibly simple night enclosures.

Past Research and Development Attempts

Comparatively little research and development work has been carried out on village chickens, despite the fact that they are usually more numerous than commercial chickens in most developing countries (Cumming, 1992) and they have been marginalized by planners and decision makers (Panda 1987), which is certainly true in Ethiopia. Few attempts have been made to increase protein supply by improving the egg and meat production potential of local birds, and upgrading and crossbreeding with exotic germplasm has been the main focus of the research and development organizations. For the last three decades, scientists and the government have promoted schemes in which cockerels from selected strains are reared up to 15 to 20 weeks of age, mainly on government poultry stations, and then exchanged for local cockerels owned by rural subsistence farmers.

The study reported by Tadelle and Ogle (1996a) in the central highlands of Ethiopia shows that there has been an introduction of exotic breeds to the three villages at various times and in different forms, as cockerels, pullets and fertile eggs, but their impact in upgrading the village chickens has been minimal. The farmers were given advice on improved feeding and housing and were asked to remove all remaining local cockerels. In addition, improved hens were introduced to boost egg production in co-operative based intensive poultry farms in rural Ethiopia, but most of these projects collapsed, mainly due to inadequate feed supply, management, medicines and discontinuation of the schemes. However these approaches led to only limited improvement, due to the high mortality rate of the modern breeds because of their lack of adaptation to the rural environment, poor management, ultimate discontinuation of the schemes and, above all, the farmers' lack of interest and awareness, because the programmes were usually planned without farmer participation and without parallel improvement in management and feeding.

Many cross-breeding projects failed because the crosses were not accepted by local people, who feared they would be vulnerable to harsh village conditions. Above all, those development strategies did not pay attention to local social and cultural aspects of poultry production. For example, farmers prefer to have double-combed cocks for sacrifice purposes, in addition to their colour preferences (Tadelle and Ogle 1996a). Local scavenging chickens, in addition to providing cash income, have nutritional, cultural and social functions which require consideration from planners, professionals and farmers, which is rarely given. However, planning and execution of research and development work on local birds could result in considerable improvement in egg production performance, and a reduction in the high chick mortality.

Tadelle and Ogle (1996) described the scavenging feed resource base (SFRB) for local birds in the central highlands of Ethiopia as variable, depending on the season and rainfall. This is in agreement with the results from three different production systems (two from Sri Lanka and one from Indonesia) (Cumming, 1992 and Roberts, 1992). So strategic supplementation of birds according to age and production status can be a suitable solution.

Generally, non-genetic factors such as poor nutrition, disease (mainly Newcastle disease) and other management practices have a much greater effect than genetics on production parameters under scavenging systems. In the results of an on-farm trial in the central highlands of Ethiopia, vaccination for Newcastle disease, improved feeding

systems, regular provision of water and small night enclosures for scavenging birds were very important as a way of achieving optimum production.

Socio-economic Aspects of Rural Poultry Production

Rural poultry represent a significant part of the rural economy. This segment of production in Africa as a whole represents an asset value of US$ 5.75 billion (Sonaiya, 1990). In addition to their contribution to high quality animal protein and as a source of easily disposable income for farm households, rural poultry integrate very well and in a sustainable way into other farming activities, because they require little in the way of labour and initial investment compared to other farm activities (Tadelle and Ogle, 1996a). A number of authors, including Veluw (1987), Sonaiya (1990), and Gunaratne *et al*. (1992), have also reported that rural poultry play a significant role through their contribution to the cultural and social life of rural people.

The existence of poultry in the household does not imply necessarily that the farmers are willing and in a position to expand poultry production. Experience has shown that intensive persuasion is needed to convince them to introduce regular watering and feeding, to clean the birds' night shelter and to take care of the young chicks, before starting any research or development programme to attain the genetic potential of the local birds. The first critical step in rural poultry development is therefore the encouragement of farmers to change their attitude towards poultry keeping and the traditional system.

It is very difficult to determine the most important purpose of keeping birds in each household because it is impossible to compare the spiritual benefit of sacrifice with the financial benefit of a sale. A ranking of purposes based on the number of birds used has very little to do with the order of importance, and understanding this is a considerable challenge for development workers. For a better understanding of the role played by poultry in the lives of rural people, it is necessary to know exactly the purposes for which households keep poultry. The five major uses and benefits of poultry and eggs in rural societies in the central highlands of Ethiopia are summarized as follows: eggs for hatching (51.8%), sale (22.6%) and home consumption (20.2%), and production of birds for sale (26.6%), sacrifice (healing ceremonies) (25%), replacement (20.3%) and home consumption (19.5%). In some cases

farmers give live birds (8.6%) and eggs (5.4%) as a gift to visitors and relatives, as starting capital for youths and newly married women. They also invite special guests to partake of the popular dish "doro wat", which contains both chicken meat and eggs and is considered to be one of the most exclusive national dishes (Tadelle and Ogle, 1996a), as confirmed by Veluw (1987) in Northern Ghana. Birds are also given as sacrificial offerings in traditional worship, and finally they perform a valuable sanitary function in the villages through eating discarded food and cockroaches, for example.

The feed resource base for the scavenging chicken production system described has no alternative use and, if they were not present, other scavengers, particularly dogs and crows would perform this function, with no associated benefit to the farming community.

Poultry keeping in most of the developing countries is the responsibility of women. Tadelle and Ogle (1996a), in a study of three villages, found that it is the women that look after the birds, and the earnings from the sale of eggs and chickens are often their only source of cash income. It is therefore important to actively involve women in the process of poultry improvement, a feature which has been neglected in the past. Most of the poultry extension workers, vaccinators and key poultry farmers are men. In some parts of Ethiopia, contacts between women and male extension workers are restricted by cultural and religious factors and information has to be passed indirectly through their husbands. It is important to plan poultry development projects in such a way that women participate actively as poultry advisers, extension workers, and vaccinators, as well as poultry farmers.

Input-output Relationships

Despite the fact that more than 70% of the poultry population in Africa (Table 1; Sonaiya, 1990) and 99% of the poultry population in Ethiopia (Alamargot, 1987) consists of local birds, their contribution to farm household and national income is not in proportion to the high numbers. Productivity is observed to increase in direct proportion to the level of confinement (Sonaiya, 1990) and other feeding and management factors, up to a certain level of production corresponding to the upper limits of the genetic potential of the local birds.

This system of production, although it appears primitive, can be economically efficient because, although the output from the individual birds is low, the inputs are even lower or virtually non-existent (Smith, 1990). The low output is expressed as low egg production, small sized eggs, slow growth and low survivability of chicks (Smith, 1990; Tadelle and Ogle 1996a) but small management changes, for example regular watering, night enclosures, discouraging them from getting broody, vaccination for common diseases and small energy and protein supplements can bring about significant improvements in the productivity of local birds (Tadelle and Ogle 1996c). In the central highlands of Ethiopia, indigenous birds kept under semi-intensive management conditions produced 100 eggs per annum and under this system of management ten clutches of eggs were produced per year as compared with three to four produced under normal scavenging systems (Tadelle and Ogle, 1996c). In general, with minimal additions of inputs, improving the existing management and changing the attitudes of farmers can bring about considerable improvements in terms of egg production, growth and increasing the level of survival.

Table 1. Percentage contribution of local birds in selected African and Asian countries to the poultry population.

Country	% Contribution	Reference
Sri Lanka	28	Fonseka (1987)
Zimbabwe	30	Kulube (1990)
Cameroon	65	Agbede *et al*. (1990)
Cote d'Ivoire	75	Diambra (1990)
Kenya	80	Mbugua (1990)
Gambia	90	Andrews (1990)
Malawi	90	Upindi (1990)
Nigeria	91	Adene (1990)

Ethiopia	99	Alamargot (1987)
Bangladesh	99	UNDP/ FAO (1983)

Feed Resources and Requirements

The feed resource base for rural poultry production is scavenging and consists of household waste, anything edible found in the immediate environment and small amounts of grain supplements provided by the women. As shown by Tadelle and Ogle (1996a and b), the scavenging feed resource base (SFRB) is not constant. The portion that comes as a grain supplement and from the environment varies with activities such as land preparation and sowing, harvesting, grain availability in the household and season and the life cycles of insects and other invertebrates. From the results of the same work, it is also possible to conclude that protein supply may be critical, particularly during the drier months, whereas energy may be critical during the rainy season, which agrees with the conclusions of Cumming (1992), who describes the feed resource as variable, depending on the season and rainfall. In the absence of an event which diminishes the flock biomass (number * mean live weight), such as disease or occurrence of a major festival, the village flock will normally be at the maximum biomass that can be supported by the SFRB. Any additions to the village flock which increase the biomass will result in increased survival pressure and selection against the weakest members of the flock.

According to the finding of Tadelle and Ogle (1996b), the feed resource is deficient in protein, energy and probably calcium for layer birds, and this is confirmed from the results of supplementation trial, which show that supplementation of local birds with food sources containing energy, protein and a calcium source brings a considerable increase in egg production.

Feed Requirements and Supplementation of Local Laying Hens

There is no doubt that feed supply is one of the main constraints to rural poultry production, and it has been calculated that scavenging birds are usually capable of finding feed for their maintenance needs and about 40 eggs

per year, but higher levels of production require supplementary feed. The nutritional status of local laying hens from the chemical analysis of crop contents, assuming this accurately reflects the feeds consumed, indicates that the %DM (52.3 �12.5), CP (9.1 �2.3), Ca (0.9 �0.4), P (0.7 �0.3) and ME (11.9 �0.9 KJ/g) were below the requirements for egg production, indicating the importance of supplementation.

Compound feeds are usually not available in remote areas, or are too expensive, so it is therefore necessary to use locally available materials such as household waste and cheap conventional and non-conventional feed resources such as brans and oil-seed cakes. The choice of raw materials for poultry feed is limited and it is not possible to formulate balanced diets in rural Ethiopia. Sub-optimal supplementary rations may be economically justified under rural conditions and accordingly this supplementary feeding should complement, but not replace, the feeds scavenged by the birds and must be tested and examined from an economic point of view. Special attention will need to be paid to local sources of minerals and vitamins, although scavenging birds would normally find a significant proportion of their requirements for vitamins and trace minerals, although probably not for calcium in the case of laying hens.

According to Tadelle and Ogle (1996c), it is possible to attain daily production per hen of over 30% using a supplement of 30 g/day maize and 30 g/day noug cake, 28% from 30 g maize and over 20% from 30 g per day per bird noug cake which is more than double the 13.9% from scavenging only. This result is also supported by the study of Islam *et al*. (1992) who showed that by giving a supplement that provided 30% of the daily energy and protein requirements of local birds it is possible to produce as many eggs as the un-supplemented Fayoumy breed in the villages, and that egg production from scavenging birds increased by a factor of three when they received a supplement covering 50% of their dietary needs.

Protein Requirements of Local Laying Hens

The protein requirement of high producing laying hens varies from 16-18% of the diet, to meet the needs of egg production, maintenance and growth of body tissues, and feather growth, but this also depends on the energy content of the feed. In addition to the above, the feed consumption and protein requirements are influenced by a

number of factors, the most important being size of the bird, stage of production and ambient temperature.

It is possible to estimate the requirements for protein factorially. According to Nesheim *et al*. (1979), a fresh egg contains 66% water, 12% protein, 10% fat, 1% carbohydrates and 11% ash. The average weight of a local hens egg is 38 g (Sazzad, 1986; Brannang and Persson, 1990; Tadelle and Ogle, 1996c). Thus a 38 g egg contains 4.56 g protein and, at an efficiency of protein utilization of 55% (Scott *et al*., 1982), hens must consume 8.29 g protein per egg. Harris, (1966) indicated that the endogenous nitrogen excretion is estimated to be 2.55 g per day for a bird weighing 1.14 kg. According to Scott *et al*. (1982), protein required for feather growth is 0.49g/bird/day. The sum total of calculated protein requirements for all these functions is 11.194 and 11.317 g/day for birds producing a 35g egg in phase one and a 38 g egg in phase two of lay. As described by Tadelle and Ogle (1996b), the mean crude protein (CP) in the crop contents is 9.1 �2.3% which is below the above calculated requirement of the local laying hens. Protein deficiency was even more serious in the short rainy and dry seasons, when the CP content of the crop contents was 7.6% and 8.7%, respectively. This is confirmed by the results of the supplementation trial reported by Tadelle and Ogle (1996c), where provision of additional protein in the form of noug cake increased egg production by a factor of two as compared with scavenging birds not receiving a supplement.

Energy Requirement of Local Laying Hens

In moderate environmental temperatures, high producing White Leghorn hens require 300-320 kcal of metabolizable energy per hen per day. Local birds are low producers of small sized eggs and their live weight is lower than that of the White Leghorn. According to Scott *et al*. (1982), the net energy requirement of adult hens is NEm= 83 kcal/kg $BW^{0.75}$. Thus for a local hen weighing 1.13 kg (overall mean), the NEm is 90.97 kcal/hen/ day. Since this figure is approximately 82% of MEm value, then 90.97/0.82 = 111 kcal/hen/day, and adding 50% of this value for activity, the total requirement for a non laying hen without travelling energy will be 166.5 kcal/hen/day. However, in addition to that, local birds need more energy for travelling, and Bessie (1989) reported that a scavenging layer travelled about 4 km per day at an average environmental temperature of 20 deg C which implies a requirement of approximately 107 Kcal per day, giving a total requirement of 273.5 kcal/day. The mean true metabolizable energy of 286 �23 Kcal from calculated values is sufficient to meet calculated requirements for a

non laying hen only.

Production and Productivity of Village Birds

The production level of scavenging hens is generally low, with only 40-60 small sized eggs produced per bird per year under smallholder management conditions. According to the results of Tadelle and Ogle (1996a), the total output of scavenging birds is low, not only because of low egg production, but also due to high chick mortality as half of the eggs are hatched to replace birds that have died, and the brooding time of the mother bird is long in order to compensate for its unsuccessful brooding. Smith (1990) estimates that under scavenging conditions the reproductive cycle consists of a 10 day laying phase, a 21 day incubation phase and finally a 56 day brooding period. This implies a theoretical maximum number of 4.2 clutches per hen each year, although in reality the number is probably 2-3.

Overall the system is quite productive in relation to the very low input levels and this is underlined by McArdle (1972) who states that the net output from poultry rearing is higher in scavenging systems compared to commercial systems, and the scavenging flock is not in competition with humans for feed. This is true if we consider the input-output relation only. Chick mortality represents a major loss in scavenging village chicken production systems (Table 2), and reports from different countries show that 50-70% of chicks die between hatching and the end of brooding.

Table 2. Reported chick mortality in rural production systems in different African and Asian countries in the first 6 to 8 weeks of age.

Country	% Mortality	Reference
Sri Lanka	65	Gunaratne *et al*. (1992)
	46	Roberts (1994)

Indonesia	79	Kingston and Cresswell (1982)
	56	Hadiyanto *et al*. (1994)
Northern Ghana	80	Veluw (1987)
Ethiopia	61	Tadelle and Ogle (1996a)
Cote d'Ivoire	50	Diambra (1990)

Kingston (1980) and Kingston and Cresswell (1982) in Indonesia, Roberts (1992) in Sri Lanka and Matthewman (1977) in Nigeria calculated mortality rates of chicks as being 69%, 65% and 53%, respectively, up to 6 weeks of age. Alamargot (1987) also reports on chick mortality in Ethiopia, and during some severe epidemics, rates as high as 80% have been recorded. According to Tadelle and Ogle (1996a), the overall chick mortality was 61 �17% (n=160) in the first two months after hatching, and is higher when there was a disease outbreak in the area. Various authors attribute these losses to different causes. For example, Roberts (1992) reported that in Indonesia losses were due to a combination of poor nutrition, predators and various disease factors and, although predators were blamed for the majority of the losses, other biological and environmental factors made significant contributions. The newly hatched chicks have access to the same feed resource base as stronger and more vigorous members of the flock but are unable to compete. In addition, the low protein and energy content of the available feed, the low hatching weight of the chicks, high ambient temperatures and other associated factors are major causes of losses, both directly, and also by increasing vulnerability to predation and susceptibility to disease.

Newcastle disease is the most important disease recognised in tropical countries in village poultry production systems (Table 3). Disease was cited as the most important problem by most of the members of the community with whom it was discussed, reducing both the number and productivity of the birds, and the problem intensified after the villagization programme in the country (1984-86). The timing of the disease outbreaks before the villagization programme was usually at the beginning of the rainy season, that is at the end of May and beginning of June, but after villagization it remains a problem throughout the year, even though it is still more serious at the beginning of

the rainy season.

Sonaiya (1990), after summarising the reports from six African countries, reported that the mortality caused by Newcastle disease ranges from 50-100% per annum and that severity is higher in the dry season, whereas the disease is more widespread in the rainy season in the central highlands of Ethiopia (Tadelle and Ogle, 1996a). The farmers do not have any preventive medicine or practice for this fatal disease, and only after the start of an outbreak do they treat their birds with socially accepted medicines (Tadelle and Ogle, 1996a). However the effectiveness of these treatments is not satisfactory.

Although the local chickens are slow growing and poor layers of small sized eggs, they are however ideal mothers, good sitters and hatch their own eggs, excellent foragers, hardy and possess some degree of natural immunity against common diseases. These traits are of great importance as the farmers cannot afford to buy expensive concentrates and incubators, which at the moment are considered necessary for raising exotic birds. Brannang and Persson (1990) reported that 50% and 75% exotic blood birds did not show any signs of broodiness at the Asela Livestock Farm. However, as reported by Panda (1987) in India, the productivity of the Kadaknath or indigenous fowl can be improved without sacrificing any of the characteristics required by village fowls. Egyptian scientists, taking a different approach, achieved significant improvements in egg production of over 21% recently by simple cross-breeding between two local strains raised in the traditional way in the near-tropical conditions of upper Egypt. This success illustrates a way of stemming the genetic erosion of local poultry breeds. Although there is a lot of evidence in the literature about genetic improvement resulting from heterosis and crossbreeding techniques with regards to egg production and growth rate, so far little research effort has been directed towards these in Ethiopia. Some information is provided by Brannang and Persson (1990), who reported average yearly egg production of 129 and 114 eggs and 48 g and 53 g mean egg weight, for birds with a 50% and 75% exotic blood levels, respectively. The only other attempt to evaluate the performance of crossbreeds with different exotic blood levels was made at Debre Zeit Agricultural Research Centre, and involved crossing local birds with White Leghorns to determine the egg production performance of the cross breeds. A preliminary analysis showed that the annual egg production of the 50% and 62.5% crosses was 146 and 193 eggs respectively (DZARC, 1991). This shows that it is possible to improve egg number and egg weight by crossing, but the results only apply to on-station conditions and no

information is available for crossbred birds kept under local farmer management conditions. In any case it is not possible to substantially improve egg production if the hens incubate and rear their own chicks.

Table 3. Reported village birds mortality caused by Newcastle disease in selected African countries

Country	% Mortality	Reference
Togo	50	Aklobessi (1990)
Sudan	50	Zubeir (1990)
Nigeria	70	Nwosu (1990)
Comoros	80	Mohammed (1990)
Ethiopia	80	Alamargot (1987)
Morocco	100	Houadfi (1990)

Conclusions

From the results of these studies it can be concluded that the scavenging system is an appropriate system for the rural areas and that it makes relatively good use of locally available resources. The requirement now is to improve these production systems in order to make the best possible use of these resources. The system is characterized by no or few inputs and a low output level. Although they appear primitive, these systems can be economically efficient because, although the output from the individual birds is low, the inputs are even lower or virtually non-existent.

The system is also characterised by huge chick mortality in the first two weeks of life, caused by different factors such as disease, predators, and the hostile environment for newly hatched chicks. The feed resource base for local

birds in the villages is from scavenging and is inadequate for the production of more than around 40 eggs/birds/year. However the results from different workers show that supplementation of energy and protein in addition to other management changes can increase egg production by more than 100%.

Rural poultry production is an important part of the farming systems and needs relatively few additional resources and inputs from farmers to achieve substantial improvements in productivity and profitability by changing to semi-scavenging systems. However, because of very high mortality rates, particularly due to Newcastle disease, farmers are generally reluctant to invest in improvements in feeding, health care and housing for example. The development of a new heat tolerant vaccine that can be administered via the feed opens up the possibility of significantly reducing mortality in village poultry, which should make producers more positive towards genetically improved birds and inputs to improve feeding and housing.

Recommendations

- **Village poultry production deserves greater attention from government, research and development organizations and, above all, from rural farmers.**
- **Preferential access to feed by the newly hatched chicks should be given through some kind of creep feeding system.**
- **Strategic supplementation of both protein and energy, providing small night enclosures, regular water and disturbing the broody bird results in more than 100% increase in egg production of local birds.**
- **Vaccination against Newcastle disease with the new heat resistant vaccine administered via the feed will substantially reduce mortality.**
- **It is important to focus on working with women's groups, both to use their knowledge about poultry production and to improve their incomes.**

- **On-farm and on-station trials on new vaccines for the prevention of Newcastle disease are needed, particularly the heat resistant vaccine which does not need cold storage and can be administered through the feed.**

- **Genetic improvement should be introduced only when the current systems have been improved in terms of dietary supplementation, housing, controlling Newcastle disease and regular water and management and, in due course, to change the system to semi-scavenging.**

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Ruminant Feeding Strategies for Sustainable Agricultural Production in Upland Mixed Farming Systems of Indonesia

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Abstract

Ruminants are an integral part of smallholder farming systems in Indonesia. However the extent and continuous nature of cropping on densely populated islands such as Java leaves little land available for grazing. Most livestock are therefore permanently housed and fed indigenous forages cut from field margins and roadsides. Cut-and-carry feeding is labour-intensive and the supply of forage is often the most expensive input to ruminant production. Surprisingly, farmers collect quantities of forage greatly in excess of the appetites of their livestock. In Experiment 1, indigenous forage dominated by *Axonopus compressus*, was offered to sheep at increasing rates: 25, 50 or 75 g DM/kg liveweight (W) daily (d). The results showed that although DM intake and W rose with increasing offer-rate, the incremental improvements from 50 to 75 were non-significant (P>0.05) and less than from 25 to 50. Rice bran is a cheap and readily available feed. It could be used to substitute for a large proportion of the expensive forage on offer. In Experiment 2, rice bran was fed to sheep at 0, 15 or 30 g DM/kg $W^{0.75}$.d in combination with indigenous forage offered at 30 or 60 g DM/kg W.d. Sheep fed the lowest cost 30/30 (forage/rice bran) diet achieved similar total DM intakes as those receiving the 60/0 diet and W gains as those receiving the 60/15 diet (P>0.05). Even when using supplements Javanese farmers persist in offering excess levels of forage to their

livestock. It is unlikely that they justify this excess feeding on the basis of marginal gains in animal productivity alone. The rationale for excess feeding may lie in greater yields of manure-compost produced from a mixture of refused forage and excreta which accumulates in pits beneath the slatted floors of their animal barns.

KEY WORDS: Excess feeding, cut-and-carry, ruminant, manure, compost, Indonesia

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Introduction

Over 60% of Indonesia's 194 million people live on the island of Java which occupies only 7% of the country's total land area. Half of Java's population are farmers (Biro Pusat Statistik, 1991) cultivating less than 0.5 ha per household (Booth, 1988). Cropping is continuous. Java is thus not only one of the most densely populated areas of the world with around 800 person/km2 , but one of the most intensively cultivated (Kepas, 1985).

Ruminant livestock are an integral part of these intensive farming systems. In 1991, over 30 and 60% of Indonesia's large and small ruminant populations respectively were located on Java despite intensive cropping leaving little land for grazing (Direktorat Jendral Peternakan, 1992). Ruminants are instead permanently housed (around two large ruminants and/or up to five small ruminants per household) in backyards and cut-and-carry fed indigenous grasses and broadleaves collected from roadsides and field margins. Cut-and-carry feeding is labour intensive making forage the most expensive input to livestock production.

Surprisingly, farmers collect large quantities of forage, often greatly in excess of the appetites of animals (Mathius & van Eys, 1983) with as much as 400 g/kg DM of that offered being refused (Little, Petheram & Boer, 1988).

The forage refusals are not wasted, they combine with faeces and urine falling through the slatted floors of the animal barns into pits where they decompose to produce manure-compost. High forage offer-rates maximise manure-compost yield. It is possible that farmers adjust their feeding rates to optimise total output from the livestock enterprise i.e. including manure-compost, as opposed to animal production per se. Manure-compost is ranked by Javanese farmers alongside offspring as the most important outputs from livestock production (Ifar,

1996).

It is hypothesized that livestock integration into Javanese agriculture is essential to the sustainability of some of the most intensive cropping cycles in the world. As intensive smallholder agriculture expands onto more marginal soils world-wide there is urgent need for developing strategies for closer integration of crops and livestock. Excess-feeding, an effective means of improving intake and productivity of ruminants fed low quality forages by providing greater opportunity for selective feeding (Osafu, Owen, Methu, Abate, Tanner & Aboud, 1996) and also generates high quality composts, may be one such strategy. The biological and economic relationships between excess-feeding, animal productivity and manure-compost production are reported in this paper.

Experiments Undertaken

Experiment 1: Effect of Quantity of Indigenous Forage Offered on Intake and Growth by Sheep and Manure-compost Yield.

Materials and methods:

Thirty Javanese Thin-tailed rams (aged 18 months, mean W 29.1 kg, s.e. 0.3) were blocked according to initial W and then randomly allocated to one of three forage offer levels: 25, 50 or 75 g DM/kg W.d. Indigenous forage, cut each morning from roadsides and field margins, comprised largely of grasses (71% of fresh weight offered) dominated by *Axonopus compressus*, with the remainder as sedges, broadleaved plants and dead plant material. The daily ration was split into two equal meals offered at 8.00 h and 12.00 h, salt licks and water were freely available. The feeding trial lasted 70 days during which intake was measured daily and W changes weekly.

Refused forage, faeces and urine were collected daily from three rams per diet, mixed and stored in slat-sided composting bins measuring 1.5x1.5x1.5m. The waste materials were collected in this manner for the last 50 days of the feeding trial and then left to compost for a further 50 days, turning every 3 days to assist aeration, before weighing and sampling for DM content.

Experiment 2: Effect of Quantity of Indigenous Forage and Rice Bran Offered on Intake and Growth by Sheep and Manure- compost Yield.

Materials and methods

Thirty-six Javanese Thin-tailed rams (aged 30 months, mean W 28.8 kg, s.e. 0.03) were blocked according to initial W and then randomly allocated to one of six feeding regimes in a 2x3 factorial design: 30 or 60 g DM/kg W.d or indigenous forage in combination with either 0, 15 or 30 g DM/k gW0.75.d of rice bran. The diets were coded as follows (forage/rice bran): 30/0, 30/15, 30/30, 60/0, 60/15 and 60/30. The daily ration of indigenous forage (of similar species composition to that fed in Experiment 1) and rice bran was again split into two meals and fed at 8.00h and 12.00h. Water and salt licks were freely available. The feeding trial lasted 42 days during which intake was measured daily and W changes weekly.

Refused forage, faeces and urine were collected from three different pairs of rams per diet over three 14-day periods. Accumulated waste materials from each pair of rams were mixed at the end of each 14-day period and composted for 50 days, turning every 3 days as described above. A quantity of forage equivalent to that which would be fed to two, 30 kg W rams on the 60/0 diet was also collected over each 14 day period to assess the profitability of composting grass directly in the absence of livestock.

Results

Table 1 shows that the DM intake and growth rate of the rams in Experiment 1 improved with offer-level but that the incremental improvement from 50 to 75 g DM/kg W.d was non significant (P<0.05) and less than that from 25 to 50. The quantity of grass refused increased substantially as a proportion of that offered from 0.109 to 0.526 by raising the offer level from 25 to 75. Allowing the rams greater opportunity for selective feeding by raising the offer-level improved the estimated N content of the diet consumed from 21.2 to 22.5 and 23.8 g/kg DM. Not surprisingly, manure-compost production rose with forage offer-level.

Table 1: Effects of increasing forage offer level on intake, ram growth rate and manure-compost yield.

Quantity of forage offered (g DM/kg W.d)	25	50	75	s.e.d
Number of rams	10	10	10	
Initial W (kg)	29.2	29.1	28.9	0.33
Growth rate (g/d)	-16.5	25.8	28.5	4.73
Intake:				
Forage offered (g/d)	3627	7772	11616	
Forage offered (g DM/d)	671	1438	2149	
Forage refused (kg DM/kg DM offered)	0.109	0.359	0.526	
Forage intake (g DM/d)	598	922	1019	
Forage intake (g DM/kg W.d)	22.1	31.7	34.9	1.16
Manure-compost yield (g/ram.d)	540	1620	2320	

In Experiment 2 (Table 2), forage and rice bran offered both had significant effects upon forage DM intake, total DM intake and forage refused as a proportion of that offered (P<0.05). Increasing the level of rice bran on offer increased bran intake but as a consequence substituted for forage intake. Increasing the rice bran offered caused a significant (P<0.05) rise in W gains at each level of forage on offer. It should be noted that rams fed the 30/30 (forage/rice bran) diet grew faster but produced less manure compost than those fed the 60/0 diet.

Table 2: Effects of increasing forage and rice bran offer levels on intake, ram growth rate and manure compost yield.

Rice bran (g DM/ kg $W^{0.75}$.d)	0	15	30	0	15	30	s.e.d
Number of rams	6	6	6	6	6	6	
Initial W (kg)	28.9	29.7	28.8	28.9	28.4	28.9	0.73
Growth rate (g/d)	-21.0	13.2	37.5	-2.4	34.5	53.6	22.8
Intake:							
Forage offered (g DM/d)	810	853	848	1702	1683	1750	
Forage refused (kg DM /kg DM offered)		0.246	0.277	0.463	0.516	0.539	0.174
Forage intake (g DM/d)	670	644	616	909	815	804	51.6
Forage intake (g DM/kg W.d)	24.3	22.3	21.3	31.6	28.5	27.1	0.62

Rice bran intake (g DM/kg $W^{0.75}$.d)	-	13.7	25.4	-	14.4	23.5	
TOTAL INTAKE (g DM/kg W.d)	24.3	28.2	32.3	31.6	34.7	37.2	1.49
Manure-compost yield (g/ram.d)	607	964	1107	2750	3071	3357	

In Experiment 1, although the high feeding levels produce the best W gains and manure-compost yields these benefits must be offset against the extra time required to supply the feed (Table 3). The most profitable ration would be that which yields the highest returns to labour (calculated as: [Value of outputs - Non labour costs]/hours of labour). The financial analysis reveals that feeding at 50 gDM/kg M.d was most profitable irrespective of whether manure-compost was considered as an output or not. The lowest level of feeding was unprofitable with the costs of production alone (excluding labour inputs) exceeding the value of growth and manure-compost production.

Table 3: Estimated cost of production (Rp1/ram.d), value of outputs (Rp/ram.d) and returns to labour (Rp/hour) when feeding indigenous forage to rams at increasing levels of offer.

	COSTS		OUTPUTS		RETURNS TO LABOUR	
Offer-rate	Labour*2 (h)	Other*3 (Rp/d)*1	Compost*4 (Rp/d)	Weight*5 (Rp/d)	Including compost (Rp/h)	Excluding compost (Rp/h)
25	0.42	18.6	18	-50	-120	-163
50	0.83	18.6	54	77	135	70

75	1.2	18.6	77	86	120	56

***1: USD 1 = Indonesian Rupiah (Rp) 2110 (1993 rate)**

***2: The lowest cost of forage input corresponds to the lowest forage offer level (25 g DM/kgW.d) and the highest forage cost to the highest forage offer level (75 gDM/kgW.d) assuming it takes 5.9 minutes to cut 1 kg of grass (derived from van Eys *et al*., 1984 and Amir *et al*., 1985).**

***3: Non-labour costs, in decreasing order of magnitude, including depreciation on the sheep barn, minerals, anthelmintics and miscellaneous expenses on ropes etc.**

***4: On average, a 30 kg sack of manure-compost fetches Rp 1000 (Holden *et al*., 1993),equivalent to Rp. 33/kg.**

***5: Assuming a sale price of Rp. 3000/kg (or Rp 3/g) (Biro Pusat Statistik, 1991).**

In Experiment 2, feeding unsupplemented forage diets gave negative returns to labour when outputs did not include manure-compost. Supplementing rams improved profitability through higher animal growth rates. Including manure-compost as an output substantially improved the profitability of all diets. However, it should be noted that it is more profitable to compost forage directly than to feed that quantity to an animal. Greater returns could however be achieved through supplementation. At the highest rate of supplementation (Diet 60/30) a farmer could increase returns to labour by around 50% compared with composting the same quantity of grass directly.

Conclusions

Excess-feeding strategies have been demonstrated to be an effective means of improving intake and productivity of small ruminants and cattle fed low nutritive value fodders such as cereal crop residues (Osafo, Owen, Methu, Abate, Tanner & Aboud, 1996). Offering excessive levels of feed inevitably produces large quantities of refusals which appears wasteful. In many smallholder situations excess-feeding may only be economically rational if other uses can be found for refusals.

Excess-feeding indigenous forages led to higher intakes and growth rates which raised returns to labour (Experiment 1). It was demonstrated that the profitability of the livestock enterprise could be significantly improved however by using the refusals and excreta to produce compost. Although, feeding at the highest offer-level yielded a positive return to labour, the calculated 'hourly wage rate' was 11% less than that obtained from feeding the 50 g DM/kg W.d diet where compost is included in the total output and 20% less where compost is excluded from outputs. A cheaper alternative to feeding high levels of expensive cut-and-carry forage might be to replace part of the diet with rice bran. In Experiment 2, feeding rams the 30/30 diet resulted in better returns to labour than the 60/0 diet. However, the most expensive diets, 60/15 and 60/30, where rice bran is fed in addition to excess levels of forage, turned out to be the most profitable. This suggests that even in circumstances where Javanese farmers are feeding rice bran they will persist in offering high levels of forage to maximise not only W gain but also manure-compost output.

The need to maximise manure-compost output is particularly acute on smallholder farms in densely populated areas where intensive cropping patterns place heavy demand upon soil nutrient status. The research shows that excess-feeding represents a financially rational feeding strategy for such production systems permitting the optimisation of animal and fertiliser outputs.

As the price of inorganic fertilisers continues to rise beyond the means of smallholder farmers, greater reliance will be placed upon livestock wastes to maintain soil fertility. However, even when the yield of organic fertiliser outputs from livestock is maximised by excess-feeding for example, the quantity of plant nutrients may not be sufficient to totally replace artificial fertilisers in a manner which is economically viable. Animal scientists should be aware that excreta is often used in combination with inorganic fertilisers. There is a need to be able to predict the influence of diet upon excreta quality and the consequences of manure handling upon nutrient loss. A better understanding of the degree to which livestock management practices influence the plant nutrient contents of animal "wastes" would provide agronomists with greater confidence to make integrated fertiliser recommendations which could, for example, capitalise upon the reported synergy between limited quantities of inorganic and organic fertilisers. The development of livestock feeding strategies for mixed-farming systems should therefore take into account not only

livestock requirements but also the nutrition of soils and crops.

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Stubble Grazing by Sheep

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Abstract

In most small ruminant systems in the Mediterranean basin and west Asia, cereal stubble is the major source of feed in late summer, when mating generally occurs. In spite of its importance, there has been little research on stubble grazing. A programme in ICARDA surveyed farm practice in northern Syria and examined the effects of stocking rate and supplementation on intake of barley stubble by Awassi sheep grazing for 28 day periods. Heads were removed in the first 4 to 8 days of grazing in a new area of stubble. Intake of stem increased when most of the leaf had been removed. Mean intakes of dry matter (DM) in 28 days were 1.10 and 0.83 kg/day in unsupplemented sheep at stocking rates of 20 and 40 sheep/ha, respectively. Intakes of ME were approximately 2.5 maintenance (M) in days 1 to 4 irrespective of stocking rate and declined to 0.70 to 0.35 M in days 23 to 28. Supplementation with 200-360 g/day of barley decreased intake of stubble in the first 4 to 6 days on a new area of stubble but, as intake was subsequently higher, total intake of stubble DM in 28 days was not affected. Supplementation with 200-360 g/day of cotton seed meal (CSM) or barley and CSM slightly increased intake of stem. Supplements, especially those with higher protein contents, had large effects on weight change and reduced the time taken for the ewes to become pregnant. More research is needed to obtain a clear understanding of the effects of different types and levels of supplementation on intake and performance in sheep grazing barley and wheat stubbles.

KEY WORDS: Stubble, barley, sheep, ewe, stocking rate, supplementation, intake

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Introduction

In the Mediterranean Basin and West Asia, livestock production and crop farming have always been integrated. Cereal stubble and straw are important feed resources not only for animals based in the areas where crops are grown but also for the very large numbers of small ruminants that graze steppe pastures and move into crop growing areas after harvest. Degradation of steppe vegetation in the last 40 years has increased the dependence of livestock production on feeds from the cropping zones (eg Boutonnet, 1989).

In many small ruminant systems in the Mediterranean and west Asia, the period in summer when stubbles are available for grazing coincides with mating and early pregnancy. As nutrition before mating and in the first month of pregnancy affects fertility and prolificacy, the stubble grazing period may have an important effect on the performance of flocks during the whole year. The start of stubble grazing often results in an improvement in nutrition and a surge in oestrous activity in breeds that, although not inherently seasonally anoestrus, often have a period of anoestrus in spring, as a result of poor nutrition or low body condition.

In contrast with the enormous number of studies on all aspects of harvested straw, little research has been carried out on grazing of stubbles or on responses to supplementation during stubble grazing. Some work has been done in Morocco (eg Guessous *et al.*, 1989 and Outmani *et al*.,. 1991) and in Spain (Valderrabano, 1991 and Cabello *et al*., 1992). There are more results from Australia (eg Mulholland, 1976), but these are of limited relevance to the Mediterranean and west Asia as both the crop and sheep husbandry are very different.

Estimates of the Quantity of Stubble

There are wide variations in the amount of dry matter present in stubble before grazing and in the proportions of straw, grain and green material. These result from a great number of factors that occur in the cereal crop before harvest (eg. seed rate, rainfall, irrigation), during harvesting (eg. cutting height, removal of straw for winter feeding) and harvesting and grazing (eg. rain storms).

Under dryland conditions estimates of total stubble mass before grazing vary from 1.20-2.76 t DM/ha for barley and 0.94-1.80 t DM/ha for wheat, with cutting heights of 14-18 cm (Cabello *et al*., 1992 and Valderrabano, 1991), to

3.5-4.0 t DM/ha for barley and 5.2-5.6 t DM/ha for wheat in Australia, at a cutting height of 45 cm (Mulholland *et al*., 1976 and Butler, 1981).

Studies of Stubble Grazing in Icarda

The programme on barley stubble started in 1991 consisted of:

- **a survey of the practice of stubble grazing on farms in Syria**
- **studies of a quadrat technique to estimate intake of stubble**
- **experiments in three successive years**

Field Study of Stubble Grazing

Thirty-nine farmers in northern and eastern Syria were interviewed about stubble grazing, to help define management decisions for subsequent experimentation (ICARDA, 1992).

The main results were:

- **farmers who had a mean flock size of 170 ewes grazed stubble for a mean of 97 days (15-160 days);**
- **they preferred barley stubble, although 13% of farmers stated that some wheat varieties were palatable and could be grazed successfully by sheep;**
- **the mean duration of grazing was 12.5 h/day (8-16 h/day);**

- **supplementation was very rare, as the stubble grazing period was considered a period of plentiful feed availablility;**
- **the combine harvester cutting height varied from 10 to 20 cm.**

Method of Estimating Intake

As rain rarely occurs in Syria before the end of October, alteration in stubble composition during the grazing period is unlikely to occur, except as a result of grazing. It was, therefore, decided to use a quadrat sampling technique to estimate the rate of removal of particular fractions and the intake of nutrients.

Examination of the stubble suggested that the use of a quadrat of the same size as the cutting width of the combine harvester (4.25 m), placed at right angles to the direction of the combine cut, would result in a systematic sampling of the stubble. A comparison of samples cut, using quadrats of 1.0 x 1.0 m (S), which had been used in earlier studies, and 4.25 x 0.47 m (R), showed a large reduction in the coefficient of variation from 23% with S to 9% with R. The means of total biomass were 1.88 +/- 8 (range 1.20-2.81) and 1.22 +/- 20 (1.06-1.54) t/ha for S and R, respectively.

In the subsequent experiments, removal during grazing of head, leaf and stem fractions was estimated by cutting 10 quadrats (5 in experiments 2 and 3) to ground level on days 0, 3, 5, 7, 9, 14, 19, 24 and 29 of each grazing period. The material was separated into head, leaf and stem. Metabolisable energy (ME) intake was calculated from 0.15 x digestible organic matter in the DM (DOMD). Daily intakes of ME and crude protein (CP) were calculated as the difference between successive samplings divided by the number of sheep and days.

Experimentation

Three experiments were carried out on barley stubble (var. Arabi Abiad) cut by combine at a height of approximately 10 cm. Mean mass before grazing was 1110, 1215 and 1140 kg DM/ha in experiments 1, 2 and 3, respectively. The proportions of head, leaf and stem before grazing were approximately 0.05, 0.55 and 0.40, with

contents of DOMD of 0.86, 0.54 and 0.36 and CP of 103, 41 and 14 g/kg DM, respectively.

Supplements were fed to the individually yoked sheep in the evening. All sheep received adequate mineral supplementation.

Experiment 1. Effect of Stocking Rate on the Intake of Stubble Fractions

Objective

To record the pattern of removal of head, leaf and stem from stubble and measure intakes of ME and CP

Design

Stocking rates of 20, 40 and 60 sheep/ha applied in 3 successive periods of 28 days

Material and Methods

- 2-year-old Awassi wethers, initial weight 55 kg
- grazed for 9.5 hr with a two hr break at midday

Results

There was a clear effect of SR on the removal of the stubble fractions. Heads were removed in the first 6-8 days on a new area of stubble and contributed 4-6%, 6-8% and 12-14% of the total intake in 28 days of DM, ME and CP, respectively (Table 1). Leaf was preferentially selected until the amount of leaf present on the stubble was low. Leaf comprised 68% of the total DM intake at SR 20 and approximately 55% at SRs 40 and 60. Total intakes of ME declined from 2-2.5 times maintenance (M) in days 1-4 to approximately 0.5, 0.25 and 0.13 M in days 23-28 at SRs 20, 40 and 60, respectively. The stubble was almost completely utilised. The wethers maintained weight at SR

20 and made substantial losses at SRs 40 and 60.

Table 1. Experiment 1. Effect of stocking rate on mean daily intakes of stubble DM, ME and CP and initial weight and weight change

Stocking Rate (ewes/ha)	20	40	60	Significance
Mean intake of DM (kg)	1.06	0.79	0.55	***
Intake of ME (MJ) Mean	8.7	6.0	4.1	***
- days 1-4	15.2	15.0	11.9	ns
- days 23-28	4.6	1.7	0.7	***
Intake of CP (g)	43	26	17	***
Initial weight (kg)	54.8	53.9	55.0	ns
Mean weight change (kg)	0.3	-2.1	-3.2	***

Experiment 2. Effects of Stocking Rate and Supplementation on Intake of Stubble Fractions

Objectives

To assess the effects of stocking rate and supplementation on the pattern of removal of head, leaf and stem,

intakes of ME and CP and on the weight changes and the time for the ewes to become pregnant

Design

2 x 3 factorial with: Stocking rates of 20 and 40 ewes/ha applied in 3 successive periods of 28 days Supplementation:

- **no supplement (none)**
- **200 g/day of cotton seed meal (CSM), providing 2.2 MJ of ME and 67 g CP**
- **200 g/day of barley (B), providing 2.7 MJ of ME and 20 g CP**

Material and Methods

- **1.5 year-old Awassi ewes, initial weight 42 kg**
- **grazed for 10.25 h with a one hour break at midday**
- **from the start of the second grazing period, two rams were kept with the ewes during the night**

Results

Supplementation with barley significantly reduced the intake of heads until day 13 and of total stubble in days 1-4, but not over the whole 28 day period, as the total intake was higher later in the period. Supplementation with CSM increased the intake of stem, but the effect was only significant when expressed as ME with mean stem ME intakes in 28 days of 2.71, 2.02 and 2,03 MJ/day for CSM, B and none, respectively. Over the whole 28 day period mean intakes of DM, ME and CP were not affected by supplementation (Table 5). In spite of the small differences in nutrient intakes from stubble, supplementation had large and significant effects on liveweight gain. The barley

supplement increased weight change from 0.1 to 2.9 kg and from -1.7 to 1.5 at SRs 20 and 40, respectively. The CSM supplement further increased gains to 4.4 and 2.2 kg at SRs 20 and 40.

As in the previous experiment, stocking rate had a significant effect on intakes of DM, ME and CP and on liveweight change. The intakes of nutrients and liveweight changes of the unsupplemented sheep were similar to those in the previous experiment.

Both SR and supplementation affected the mean number of days for the ewes to become pregnant, which was much greater in the unsupplemented ewes at the higher SR.

Table 2. Experiment 2. Effect of stocking rate and supplementation on mean daily intakes of stubble DM, ME and CP and initial weight, weight change and days to become pregnant

Stocking rate (ewes/ha)	--- 20 ---			--- 40 ---			Signif.	
Supplement	CSM	B	None	CSM	B	None	SR	Supp
Mean intake (kg DM)	1.19	1.14	1.09	0.93	0.85	0.82	***	ns
Intake of ME (MJ)								
- Mean	10.0	9.2	9.3	6.4	5.9	6.2	***	ns
- days 1-4	16.9	8.9	14.8	11.7	10.1	13.4	*	**
- days 23-28	4.9	5.0	3.1	1.7	2.0	1.8	***	ns
Mean intake of CP (g)	46	48	49	31	28	31	***	ns

Initial weight (kg)	43.0	41.8	40.9	43.0	42.0	43.5	ns	ns
Weight change (kg)	4.4	2.9	0.1	2.2	1.5	-1.7	***	***
Days to become pregnant	30	40	36	42	29	66(1)	***	**

(1) = mean of 6 ewes, as 2 ewes failed to become pregnant

Experiment 3. Effects of Stocking Rate and of Level and Type of Supplement on the Removal of Different Stubble Fractions

Objectives

To assess the effects of stocking rate and supplementation on the pattern of removal of head, leaf and stem, intakes of ME and CP and on the weight changes and the time for the ewes to become pregnant.

Design

2 x 3 x 2 factorial with two replications: Stocking rates of 20 and 40 sheep/ha applied in 2 successive periods of 28 days Supplementation with two diets at two levels of intake:

- **no supplement (none)**
- **300 and 150 g/day of barley (300B and 150B), providing 3.6 and 1.8 MJ of ME and 27.0 and 13.5 g CP, respectively**
- **320 and 160 g/day of a mixture of 65% barley and 35% cotton seed meal (320M and 160M), providing 3.6 and 1.8 MJ of ME and 54 and 27 g CP, respectively**

Material and Methods

- **1.5 year-old Awassi ewes, initial weight 40 kg**
- **grazed for 9.30 h with a one hour break at midday**

Results

Supplementation had significant effects on the intake of stubble in all periods, but, as intake was initially depressed in days 1-6 and subsequently increased by feeding supplements, mean intake over 28 days was not significantly different between treatments. Intake of stem was affected by supplementation, but, in contrast to experiment 2, was higher with the barley supplement. Although supplementation did not significantly affect total intake of stubble DM, ME or CP, it had a large effect on weight change (Table 3). As in the previous experiments, there were significant effects of SR on intake of stubble and liveweight change. The mean number of days for the ewes to become pregnant was affected by both SR and supplementation.

Table 3. Experiment 3. Mean daily intakes of stubble DM, ME and CP and initial weight and weight change

Stocking rate (ewes/ha)	--- 20 ---			--- 40 ---			Signif.	
Supplement	M(1)	B(2)	None	M(1)	B(2)	None	SR	Supp
Mean DM intake (kg)	1.09	1.16	1.15	0.85	0.92	0.87	***	ns
ME intake (MJ)								
Mean	11.1 11.5		10.9	6.8	7.6	7.3	***	ns
- days 1-4	22.3	18.7	17.4	13.6	14.1	16.4	0	ns

- days 23-28	6.6	6.3	5.8	2.4	3.0	2.8	***	ns
Mean CP intake (g)	41	41	48	25	29	27	***	ns
Initial weight (kg)	39.9	39.2	38.4	40.6	40.4	40.1	ns	ns
Mean wt change (kg)	7.1	3.8	0.6	3.0	0.6	-1.2	***	***
Days to get pregnant	15	29	42	30	45	46	***	***

(1) = Mean of treatments M320 and M160

(2) = Mean of treatments B300 and B150

Conclusions

The results of these experiments show that, where there is no rain in the grazing period, the patterns of removal of the different stubble fractions can be described, using frequent sampling with a quadrat the same length as the combine cutting width, which allows systematic sampling of all the material on the stubble.

There were clear patterns in the removal of different fractions from stubble by grazing sheep. Heads were selected first and removed in the first 4 to 8 days of grazing at stocking rates of 20-60 sheep/ha. Intake of stem increased when most of the leaf had been removed. Mean contributions of head, leaf and stem to total DM intake on the unsupplemented treatments in the three experiments were 7, 64 and 29% at SR 20 and 5, 61 and 34% at SR 40. Supplementation with barley decreased intake of stubble in the first 4 to 6 days on a new area of stubble but, as intake was subsequently higher, total intake of stubble DM in 28 days was not significantly affected. Intake of stem was increased by supplementation with CSM in experiment 2, but not by the supplement with a higher protein

content in experiment 3. Supplements, especially those with higher protein contents, had large effects on weight change and reduced the time taken for the ewes to become pregnant. More research is needed to obtain a clear understanding of the effects of different types and levels of supplementation on intake of stubble by sheep and on their performance.

In view of the importance of stubble as a source of feed in small ruminant systems in west Asia, more research is needed on grazing not only of barley, but also of wheat stubble, under dryland farming.

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Feeding Draught Milking Cows in Integrated Farming Systems in the Tropics - Ethiopian Highlands Case Study

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Abstract

The evaluation of multipurpose cattle (milk, meat and work) is of importance in many tropical regions because of its direct and indirect effects on livestock and crop production.

The costs and utilisation of dietary nutrients are major determinants in the evaluation of the biological efficiency of multipurpose cows. Work can lead to a competition for energy precursors which may affect milk production and reproductive efficiency.

This paper deals with studies on work output, feed utilisation and lactation of crossbred (F1 Friesian and Simmental x Boran) dairy cows used for draught in the Ethiopian Highlands. Over a period of three years, work output of dairy cows averaged more than 200 MJ per cow per year of net energy which was greater than that required by farmers for land cultivation. The diet fed to cows contained 18 g/kg of N, 613 g/kg NDF (composed of 75% natural pasture hay and 25% concentrate). Work increased dry matter intake of roughage and in vivo dry matter digestibility by 10.7 and 6%, respectively. Digestion kinetics could explain only partially the possible mechanisms responsible for greater roughage intake and digestibility in working cows. How work could affect either rumen fermentation processes or digestion in the lower digestive tract, as well as other processes involved in intake regulation of roughage diets, is uncertain.

Milk yield of two consecutive lactations was not significantly different for non-working and working cows. On-farm milk production of cows over a period of two years was similar for working and non-working cows (2,620 v. 2,980 kg, respectively).

Supplementation of working cows reduced liveweight loss by 73% and doubled the number of conceptions and parturitions compared to non-supplemented cows. Working cows that lost more than 15% of calving weight conceived when they had recovered 55% of their weight and 106% of their body condition loss, respectively. Even after extended periods of underfeeding, acyclic and anoestrous cows resumed ovarian cyclic activity in an average of 46 days and conceived in 75 days when fed about twice their maintenance energy requirements.

The economic analysis indicated that the value of work more than compensated for the small reduction in milk production and longer calving interval found in working cows when supplementation took place to ensure adequate nutrition.

In conjunction with the technical factors, systematic consideration needs to be given to the effects at the micro-level of socio-economic factors, including institutional and structural factors. The successful introduction of crossbred cows for milk and traction not only requires new feed production, feeding and management systems on-farm, but also would induce substantial changes in present mixed farming system practices. Therefore, there is a need to identify those technical and socio-economic factors which might affect such changes and hinder or promote these technologies.

KEY WORDS: Draught animal power, multipurpose, cow, milk, feed, Ethiopia

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Introduction

In many developing countries, draught animal power is the best alternative power source at the intermediate technology level, because low wages and small farm size make it unattractive to substitute tractors.

The efficiency of animal traction in the smallholder context could be increased by adopting multipurpose animals to be used for meat and milk production as well as for draught power. Cows can use feed resources more efficiently than oxen and, if properly fed, can provide adequate work output for most cultivation practices (Matthewman, 1987). The use of cows for draught would allow males to be fattened and sold younger, and could also lead to greater security of replacements. More productive animals on farms could result in a reduction in stocking rates and overgrazing, thus contributing to the establishment of a more productive, sustainable farming system. Peri-urban farmers would be more inclined to change or modify their management system since their proximity to urban services would help minimise production risks (Gryseels and Goe, 1984).

In a growing number of tropical regions, cows are being used for draught particularly in areas where human population pressure on land has reduced farm size and thus has caused a decrease in feed resources for livestock (Matthewman, 1987). Research on the evaluation of multipurpose cattle (milk, meat and work) is of primary importance because of its direct and indirect effects on livestock and crop production. ILRI and the Ethiopian

Institute of Agricultural Research (IAR) have studied different aspects of the use of dairy cows for draught work. This paper deals with on-station and on-farm studies on work output, feed utilisation and lactation of crossbred dairy cows used for draught in the Ethiopian Highlands. Information generated from ILRI and IAR research is used to elaborate the inter-play of factors affecting work output and lactation performance of dairy cows used for draught.

Work Output and Efficiency of Draught Dairy Cows

Results from Zerbini *et al*.,(1992) show that F1 crossbred dairy cows (Friesian x Boran and Simmental x Boran) were able to work at a rate of about 500 W. This represented about 14% of mean body weight with a work efficiency ranging from 7% to 26%. Over a period of three years, work output of dairy cows averaged more than 200 MJ per cow per year of net energy which was equivalent or above that required by farmers for land cultivation.

Feed Utilization in Multipurpose Cows

Feed is a dominant factor in animal production because of its major effect on milk yield, reproduction and work capacity. Furthermore, the costs and utilisation of the energy and nutrients in the ration are of great importance in the evaluation of biological efficiency of a multipurpose animal. Feed efficiency in cattle is influenced by diet and other environmental factors, genetic potential and physiological state of the animal (Korver,1988; Zerbini and Alemu G/Wold, 1995). Selection on gross feed efficiency could be relevant for multipurpose cows where the genetic correlation between work capacity or work output and feed efficiency has not yet been established.

Draught cows have higher nutrient requirements than oxen specially if they have to perform draught work during the early stages of lactation when nutrient supply has to cover the needs for work, lactation and reproductive activity. Under conditions where adequate feed is not available to maintain body weight, cows can still satisfactorily perform work by drawing on body reserves, but other functions such as lactation and reproduction could be impaired.

In multipurpose cows, especially those fed on poor quality diets, work may lead to competition for energy precursors which may in turn have an effect on milk production and reproductive efficiency. This effect could be greater than that occasioned simply by competition for energy-producing nutrients per se. When work is imposed on the lactating cow, it affects the partition of energy yielding substrates to the muscle and free fatty acids are mobilized from fat depots. At the same time, these metabolites are also precursors of milk components and competition will occur with other functions in the lactating, working cow. The diversion of amino acids away from protein synthesis might also be due to requirements by cows for glycogenic substrates to substitute for some of the roles that glucose normally plays under situations of glucose sufficiency. This is especially important in the dairy cow where glucose and amino acids are being used for milk synthesis in the mammary gland or in the gravid uterus.

Genotype may be important in the selection of cows that will adapt to draught work with minimal disruption to lactation. In addition, different physiological priorities in beef and dairy breeds will affect the efficiency of energy use and maintenance. A desirable trait of the lactating, working cows would be a large food intake capacity. Larger animals could be of considerable advantage in situations where high fibre roughages are utilised. Larger animals are more efficient chewers and spend less time chewing per kg of ingested cell wall constituents.

Multipurpose Cows: Performance in the Ethiopian Highlands

On-station Studies

Location and diet

The study was carried out at the Holetta Research Centre of the Ethiopian Institute of Agricultural Research (IAR) which is located in the central highlands of Ethiopia, 50 km west of Addis Ababa, at an altitude of 2400 m and with an annual rainfall of 1060 mm. Mean maximum temperatures range from 18.7 to 24.0 deg. C.

Crossbred cows (Friesian x Boran and Simmental x Boran) worked 4 hours/day, 100 days/year for three years. Work started two weeks after and was stopped one month before the expected calving date. Mean body weight of the cows was 412 kg. The diet was formulated to meet nutrient requirements of cows for maintenance, milk

production, pregnancy and work (Australian Agricultural Council, 1990) and included natural grass hay fed ad libitum, 3 kg of concentrate (mix of 800 g/kg of noug cake (Guizotia abissinica), 150 g/kg of wheat mids, 30 g/kg salt and 20 g/kg bone meal; 25% CP and 11.4 MJ ME/kg DM) and mineral lick. Chemical composition and degradability parameters of the diet are shown in Table 1.

Table 1. Chemical composition and degradation characteristics(1) of the diet(2) fed to F1 crossbred cows used for draught.

	mean	s.d.
Dry matter	907	11
Organic matter	900	17
Nitrogen	18.0	2.1
NDF	613	40
a	18.9	0.7
b	52.9	4.8
c	0.03	0.004

1 Orskov and McDonald (1979)

2 Include 75% natural pasture hay and 25% concentrate.

Diet intake and utilization

Dry matter intake was greater for working compared to non-working cows (Table 2). Working cows increased DMI

above that of non-working cows by 10.7% over a period of three years. Work increased DM and OM in vivo digestibility. Working cows must have absorbed more nutrients as indicated by the greater intake and greater digestibility of the feed. Digestion kinetics could explain only partially the possible mechanisms responsible for greater roughage intake and digestibility in working cows (Zerbini *et al*., 1995).

A number of studies have reported no significant effect of work on feed intake in oxen (Lawrence, 1985) and buffalo cows (Bakrie and Teleni, 1991). Other studies indicate an increased feed intake in working buffalo cows (Ffoulkes *et al*., 1987) and dairy cows (Gemeda *et al*., 1995). Furthermore, some authors have reported negative or no effect of work on digestion in buffalo and cattle, depending on the diet fed (Pearson and Lawrence, 1992; Pearson, 1990), while others have shown a positive effect of work on digestibility (Pearson and Lawrence, 1992; Ffoulkes *et al*., 1987).

Table 2. Organic matter digestibility and cumulative dry matter intake and work output of F1 crossbred cows used for draught over a period of three years.

Treatment	n	% Dry matter digestibility	Dry matter intake(kg)	Work output (MJ)
No work	10	51.0	10,603	-
Work	10	54.0	11,841	705.2
s.e.		0.7	375	-
F Work		P<0.05	P<0.05	-

How work could affect either rumen fermentation processes or digestion in the lower digestive tract, as well as other processes involved in intake regulation of roughage diets, is uncertain.

Degradation rate was not measured separately in working and non-working animals. It is, however, unlikely that physical work of the animal could affect the microbial degradation rate of fibre. Increased body temperature observed in crossbred cows at work (Zerbini *et al*., 1992) could decrease gut motility, increasing retention time of feed in the rumen and feed digestibility. However, a decreased rumen retention time of solids due to work was not apparent.

Live-weight change and reproduction

Cows tended to maintain or gain body weight over three years. Body condition score was similar between working and non-working cows at the end of three years from the beginning of the study. Over a period of two years, supplementary feeding reduced body weight loss of cows by 80%. Supplementation of working cows reduced liveweight loss by 73% and doubled the number of conceptions and parturitions compared to non-supplemented cows.

Calving intervals of working cows (Table 3) were on average 90 days longer than those of non-working cows. Differences were greater and significant in the second calving interval.

It is possible that the depletion of body reserves to certain critical levels had signalled metabolic controls to switch off non-vital processes such as ovarian function. A clear definition of body weight and condition at the start of the work season and rate of weight loss which are compatible with normal ovarian activity is desirable, as well as the effect of interaction between work and body reserve nutrients on cyclic activities in cattle and buffaloes.

Work did not influence the conception ability of supplemented cows, but had a substantial influence in non-supplemented cows.

Table 3. Calving intervals of F1 crossbred cows used for draught over a period of three years.

Treatment	Calving intervals			

	n	1	n	2
No work	10	415.6	8	397.8
Work	9	491.6	7	502.0
s.e.		31.2		31.5
F work		NS		P<0.05

Lactation parameters

Ninety per cent of non-working and 70% of working cows completed two lactations over a period of three years (Table 4). Milk yield of two consecutive lactations was not significantly different for non-working and working cows. However, days in milk were significantly greater for working cows.

The greater calving intervals observed in working cows is consistent with the delay in conception after parturition reported for working/supplemented compared to non-working/ supplemented cows by Zerbini *et al*. (1993). The relatively fewer number of lactations completed as well as conceptions, and greater days in milk of working cows, over a period of three years, reflects the delayed conception in working cows. Once pregnancy was established there was no effect of work on maintenance of pregnancy

Table 4. Lactation yield (kg) and days in milk of F1 crossbred cows used for draught

Treatment	Lactation 1			Lactation 2		
	n	milk yield	days	n	milk yield	days
No work	10	1777.7	321.0	9	1446.7	303.3

Work	10	2010.8	443.2	7	1685.5	427.0
s.e.		247.7	38.3		181.8	41.0
F work		NS	P<0.5		NS	P<0.07

Even under conditions where adequate feed supplementation was not vailable to maintain body weight, such as for working/ non-supplemented cows, animals could still satisfactorily perform work by drawing on body reserves and increasing dry matter intake. However, Gemeda *et al*. (1995) indicated that if such a situation exists for as long as one year, cows could lose more than 15% of their calving body weight and reduce milk production by more than 50% compared to working/ supplemented cows.

Working cows that lost more than 15% of calving weight conceived when they had recovered 55% of their weight and 106% of their body condition loss, respectively. Body weight gain appears to lag behind condition score increases and recovery of body weight seems to be less important than recovery of body condition for conception to occur. Even after extended periods of underfeeding, acyclic and anoestrous cows resumed ovarian cyclic activity in an average of 46 days and conceived in 75 days when fed about twice their maintenance energy requirements. The economic implications of long periods of low productivity or maintenance in working and non-working cows, and the requirements for resuming reproductive activity, need to be evaluated in detail especially for farming systems with large fluctuations in availability of feed resources.

On-farm Studies in the Ethiopian Highlands

The on-farm testing of cow traction technologies was designed to evaluate the effect of draught work and management on production and economic performance of crossbred dairy cows on the smallholder farm. The approach used in testing the dairy-draught cow technology and its transfer on-farm has been interdisciplinary.

Pairs of crossbred cows (120 F1 Friesian x Boran) were purchased by selected farmers in 1993 and 1995 in the Holetta area. Stratification of participating farmers into low, middle and high income groups was based on land and

livestock holdings, livestock type and labour availability, total farm assets and location.

Preliminary on-farm research results on cows performance (Table 5) have shown that milk production of working and non-working F1 crossbred cows on-farm was similar (2620 vs 2980 kg), ranging from 2010 to 3,400 kg for working cows and from 2018 to 3907 kg for non working cows. Calving intervals for working and non-working cows were 525 and 495 days, respectively. First lactation average milk yield and days in milk of working and non-working cows were 1,864 and 2252 and 376 and 410 days, respectively. Service per conception for working and non-working cows were similar. Over a period of two years cows worked an average of 26 days/year.

During working days, energy requirements of cows could increase by more than 1.5 maintenance. Increased feed requirements could be met by production and feeding of mixtures of grasses and legumes to increase digestibility and energy intake of cows to levels which would allow them to support both milk production, reproduction, and work with acceptable physiological body weight loss. Alternatively, feeding of natural pasture hays and improved quality crop residues associated with concentrate feeding or multipurpose tree foliage during early lactation and pregnancy could allow optimal performance of draught cows and make effective use of on-farm resources. Application of technologies for better use and conservation of natural sources of fodder during particular periods of the year needs particular attention.

Table 5.Performance parameters of draught crossbred cows under on-farm conditions.

Parameter	Working cows (n=14)	Non-working cows (n=14)
Milk Production (first lactation, kg)	1,864	2,252
Milk Production (two years, kg)	2,620	2,980
Calving Interval (days)	525	495

Lactation Lengths (days)	376	410
Service per conception (No.)	2.1	1.9
Work days/Year	26	0

Anthropological Survey

An anthropological survey of farmers participating in the project and non-participating farmers suggests that, despite reservations, many farmers are willing to try cows for milk and draught work. Those who believe that cows can plough are younger and better educated, have slightly smaller households, and considerably smaller crop land, grazing land and herd size. More than a third of the farmers objecting to cow traction believe that there are pragmatic problems while less than a quarter believe there are cultural or technical problems. The most important technical problem mentioned by farmers relates to the cows' ability to plough and give milk simultaneously. Social reasons against cow traction relate to community pressure to stick to existing norms of behaviour, and the fear of acting in ways which do not conform. Cultural, moral and social reasons for not using cows for traction appear to be given when there actually are more important underlying reasons which can be overcome with sufficient farmer testing of the technology (Pankhurst, 1995).

While in the medium term the technical feasibility and the investment/cost ratio, as well as social factors, will affect the acceptance of cow traction technologies, in the long run, the diffusion of crossbred cows will depend on the extension of the results of the study. The environment for dairy development, including government policies and services, especially credit, veterinary and breeding services, will also be critical.

Indicators for on-farm cow traction technology adoption could include: 1) farmers continuing to use cows for ploughing after the research project ends; 2) farmers who have received crossbred cows reducing the number of their local cattle; 3) farmers in the research area who were against cow traction changing their mind; and 4) new farmers spontaneously adopting cow traction technologies.

Economic Implications

The potential of the use of crossbred cows for milk production and traction was substantiated by simulating the production parameters and investment returns over a three-year period using the ILCA bio-economic herd model (Shapiro *et al*., 1994). The effect over time of introducing crossbred dairy cows into a typical farm herd of local cattle for work and milk production were also simulated and compared to using the local cows for milk production and local oxen for traction. Then the financial implications were investigated using incremental benefit/cost analysis. The incremental benefit/cost ratio of having supplemented working cows over the traditional system of local cows and oxen is about 3.5 and the internal rate of return (IRR) is 78%. The incremental benefit/cost ratio is high because of the very high productivity of the crossbred cows (5-6 times milk yield) relative to local cows.

The value of work more than compensated for the small reduction in milk production and longer calving interval found in working cows when supplementation took place to ensure adequate nutrition. The greater returns on investment in supplemented, working crossbred cows was thus mainly a result of the higher value of the work output, in spite of the higher feed costs and lower off-take (milk and calves).

In conjunction with the technical factors, systematic consideration needs to be given to the effects at the micro-level of socio-economic factors, including institutional and structural factors. This research would also help policy makers to choose more effective policies and programmes to develop and promote widespread diffusion of new technologies.

Conclusions

The results from this study indicate that draught work induced an increase in forage intake and digestibility. The attempt by working cows to increase intake to meet energy requirements even when fed relatively poor quality forage is important. Further experimentation needs to be conducted to identify and evaluate important traits in multipurpose cattle which could allow increased efficiency of resource utilisation. These traits could then be used in crossbreeding and selection programs to produce the most appropriate cattle type to optimise utilisation and

equilibrium of on-farm resources. Genetic aspects of traits related to feed utilisation and work capacity should receive particular attention.

The successful introduction of crossbred cows for milk and traction not only requires new feed production, feeding and management systems on-farm, but also would induce substantial changes in present mixed farming system practices. Herd composition and requirements of farms are expected to substantially change, and result in a more efficient/higher productivity system (Shapiro e al., 1994). Therefore, there is a need to identify those technical and socio-economic factors which might affect such changes and hinder or promote these technologies.

As regards feeding multipurpose animals, much fundamental work still needs to be done to obtain a better understanding of the factors which affect the partition of nutrients between work, milk production and liveweight gain. In particular, their preference over oxen could contribute to a better utilisation of already scarce feed resources. Additional research should be done on the management and nutritional requirements of the lactating draught cow and possible ways to meet its nutrient needs, especially in early lactation when the high energy demand for lactation is associated with work energy needs. Research and extension must therefore determine ways of producing adequate feed on the farm for draught animals and to evaluate locally available sources of supplements

Multidisciplinary research projects should investigate the technical and economical relationships between alternative combinations of animals, implements and soil in diverse regions. A system-analysis-approach-based model should be developed to describe the systems.

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