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ANIMAL PRODUCTION IN A GRAIN HUNGRY WORLD

– or competition between man in a resource limited world.

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I do not know if the persons who devised the theme of this Conference, "Animal Production in a Grain Hungry World", foresaw that it raised some of the most fundamental issues facing man. But the issues are not new; they must have been raised many times over the thousands of years of agriculture whenever food which could have been used by man was directed to livestock despite human need for it. But it is now being raised more and more insistently as increasing world populations and so food needs sensitize the world community to the actual or potential competition between man and animals for food. As a result a not uncommonly expressed view is that animal production, particularly based on grain, must be a diminishing and eventually insignificant component of world agriculture. Evidence and arguments in support of this view are ready to hand:

- as mixtures of plant foods can supply all the energy and essential nutrients needed by man, except for vitamin B12 which can be supplied by fermented plant matter, animal products are not essential in human diets; and the emerging high lysine grains make nutritionally adequate plant-based diets potentially easier to achieve

- as energy ("calories"), not protein (essential amino acids) is the first limiting factor in the diets of most chronically underfed people of the world and in famine, there is no special case for increasing production of animal products because of their high protein content and high quality of protein.

- as at least 80 percent and usually much more of the energy of plant matter is lost in converting it to animal products, animal production is energetically inefficient and wasteful

- because of this, it is immoral to feed animals on grain or other materials which could be eaten by man

- animals play no vital or irreplaceable role in the functioning of agro-ecosystems, as pure crop production systems can be highly productive.

The view of a likely diminishing role of animal production can then seem to have good support. But let us evaluate the arguments.

Animal products are not essential in human diets. This is a valid statement. But man does not 'live for bread alone', nor select his diet primarily to supply nutrients. He lives for quality of life; and quality of diet is a major component of this, with animal products – meat, milk and eggs – highly preferred foods in the diet of most peoples of the world. The main restraints on consumption of animal products are price and income; the elasticities of demand for animal products are high.

Also in many situations, especially with young children and lactating women, animal products can be the most suitable supplements for otherwise inadequate diets; and even in the poorest countries and in all but the poorest sectors of their communities animal products are usually a significant component of diets, particularly as sources of protein, B vitamins and calcium.

Can processed plant proteins simulate and so replace meat? they are being increasingly used for mixing with ground meat as 'meat extenders', but as this can reduce the price of what is primarily a meat product it may in fact increase the market for meat. Meat analogues based on woven plant protein fibres which replicate some of the organoleptic properties of meat present a challenge to meat in processed foods, and with improved technology they may even challenge fresh meat. (See Gardner, 1976). The outcome of this competition between meat and meat analogues will be determined by price, and the degree to which people can be persuaded to replace meat with a technological product. However the technology required to produce them makes them unsuitable for most developing countries. So that while animal products are certainly not essential in human diets, and processed plant proteins may increasingly compete with them, this is not a sufficient basis for concluding that the days of animal production are numbered.

Energy is the first limiting factor in most human diets so that there is no special case for increasing production of animal products because of their high protein content. This contrary view to what was widely held until recently has been forced by dietary and clinical surveys which have shown no evidence of widespread protein deficiency in developing countries, particularly on grain and grain and pulse diets, and by experimental evidence which has led to scaling down on minimal protein re-

quirements of humans so that diets previously considered inadequate are now accepted as adequate. Protein deficiency certainly occurs, but it is mainly in young children weaned on to low protein food (kwashiorkor) and in lactating women, and is usually associated with economic deprivation, ignorance, and competition within the family for the higher protein foods rather than absolute shortage of available protein or lack of capacity to produce it.

Deficiencies of nutrients such as thiamin, ascorbic acid, vitamin A, iron, calcium and iodine can under some circumstances be extremely important. But dietary surveys show that the main cause of differences in nutritional status of people between and within countries is differences in energy intake and the main cause of this deficiency is usually not direct lack of food or low food production potential of the countries but **poverty**. Large sectors of communities are just not able to buy sufficient food, or retain enough if they grow it as well as pay for other essentials such as clothes, fuel and school fees. When food is in short supply and prices rise they are even more disadvantaged. Increasing the proportion of protein in the diets of these people would not improve their nutrition as the extra amino acids would be deaminated and used as a source of energy.

It must then be concluded that the greatest need for improving the nutrition of most underfed people of the world is to increase their energy intake. But as the main cause of low energy intake is economic deprivation, improving their energy intake means improving their economic status.

(The question of whether an energy intake which allows maximal growth and adult size is essential for optimum human performance must also be considered. Only recent generations of western countries have manifested their genetic potential for growth as nutrition and hygiene have improved and Japanese generations are still improving in height; and once people have survived the first five years of life their life expectancy is in fact similar in all countries. The increased maintenance energy requirement of larger persons also increases the national food needs. Much of the health problems of developed countries arise from excessive energy intakes.)

It is valid to conclude then that because of the overwhelming importance of energy as a limiting factor in diets in less developed countries, no special case can be made for animal products because of their high protein content. But nevertheless I will show that animal production can be important in improving human energy intake. The evidence also indicates that the main requirement for feeding future human numbers will be increased energy production.

Animal production is energetically *inefficient and wasteful*. It is true that at least 80 percent and usually more of the digestible food energy intake of animals is lost as heat, because of their maintenance energy requirement and the energy loss in converting absorbed nutrients to meat, eggs and milk. So that on this criterion of efficiency animals are 'inefficient and wasteful'. But the energy in plant matter is solar energy converted by photosynthesis, and solar energy is for practical purposes virtually a non-limiting resource. The potential efficiency of conversion of solar energy to chemical energy in plants is about 4–5 percent, and at present less than 0.1 percent of the solar energy falling on land is converted to human food; so that there is a margin of some fifty-fold between the present and potential rates of food energy production. Solar energy can also be looked on as virtually a "free good". Land which receives the highest annual and daily rates of solar energy inflow, deserts and land in high latitutes respectively, have the lowest economic value of all land. The monetary value placed on land for agriculture is determined by the cost of inputs required to produce a unit of marketed product, not its rate of solar energy inflow. These inputs are the labour, tools, machinery, seed, chemicals, fuel, fertilizers, etc. used in the processes of clearing, cultivating, sowing, irrigating, fertilizing, harvesting, transporting, etc. in producing the product. Where there is a small input at low cost and high potential output per area, as with fertile easily worked soils, reliable rainfall and proximity to markets land is highly valued and vice versa.

The question of whether animals as a source of food are 'inefficient and wasteful' compared to plants is then not answered by the argument that animals waste 80 percent or more of their ingested food energy as the wasted energy is converted solar energy which is essentially an unlimited resource and free good. The basic criterion efficiency must be the input other than solar energy required to produce a unit output of food for man; and as energy is the main limiting factor in human diets and will be the main need for feeding future human numbers, the food is best measured as energy. The conventional measure of inputs is money. But money in its physical sense is an unlimited resource, and cycles in economies; it is not wasted in the sense that animals are said to use or waste energy, or materials are wasted. Money is only a token for the physical inputs. The basic need in considering efficiency is therefore a means of lumping together the physical inputs, from human labour and machines to fuels and fertilizers, involved in producing a unit of food energy. Classically such inputs are regarded as capital, labour and land; and Marx's view was that capital was essentially the accumulated product of labour. But as human labour is basically expenditure of energy derived from food in turn derived from the non-limiting resource of solar energy, and as 'land' in terms of area for intercepting solar energy is not limiting, this approach does not help a great deal in considering questions of efficiency.

There is now a growing recognition that a funda-

mental basis of comparative efficiency for producing things, from food or metals to information, is the input of *energy* other than inflowing solar energy required to produce it; that is, the energy used by man in his total processes of manipulating the environment for producing food, metals, materials, machines, building, fertilizers, chemicals and, by research, information. This energy has been termed *ancillary energy* (from the Latin *ancilla,* a servant) to distinguish it from energy in food (McClymont, 1973). There are very cogent reasons for regarding this energy as a fundamental basis of efficiency. Materials in the sense of the atoms which make them up are essentially unlimited as the atoms of materials are never destroyed, except in nuclear fission, and are theoretically available for re-use by re-cycling and re-synthesis. That is there is no depletion or loss of elements, except uranium used for energy, only depletion of the richer sources of them which require lower energy expenditure to exploit. With sufficient energy and acceptance of the environmental cost no mineral source is finite, as even granite or sea water can supply all needed elements; so that depletion of the richer mineral sources can be equated with pre-empting future energy resources (see Brooks and Andrews, 1974). On the other hand as our everyday experience tells us energy cannot be recycled; it flows uni-directionally from sources to sinks, or free energy to entropy (Second Law of Thermodynamics).* In this flow it can be interconverted into chemical, mechanical and electro-static energy (First Law of Thermodynamics) with some loss of energy as heat at each conversion. Ultimately it is all converted to entropy or randomly diffused energy unavailable for doing work. The earth's sources of energy are inflowing solar radiation and its converted forms of hydro-electricity, wind and waves, accumulated solar energy as fossil fuels and plant matter, nuclear energy, geothermal energy and tidal energy, and the ultimate sink is cosmic space into which heat energy is radiated as long wave infra-red from the earth's surface. In contrast to inflowing solar energy the fossil fuel sources, oil, natural gas and coal and uranium 235 are finite and non-renewable and are being depleted at an increasing rate; and hydro-electric, geothermal and tidal energy are obtainable only at restricted sites at finite rates. The high energy cost of producing usable energy from shale and tar sands and the limitation to rates of energy production from them because of other resource limitations in particular water indicate that these sources will not be major ones. Human labour based on food energy produced without non-renewable resources of ancillary energy could also be looked on as virtually a potentially unlimited source of energy.

Solar energy harvested as heat or direct conversion to electricity or by harnessing wind and wave power, nuclear breeder reactors may eventually provide a near-infinite source of ancillary energy.* But whether and if so when these sources will be available in quantity, whether nuclear breeder reactors will be accepted, and the economics of these sources are still speculative. However it is becoming increasingly clear that none of these sources will be available in quantity in the next few decades when the current major sources of energy, oil and natural gas, and also uranium 235 will be declining in availability and so increasing in cost; and there will be increasing dependence on coal which is a more plentiful but still finite resource and a more costly source of energy, particularly liquid fuels, than oil and natural gas have been.

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*The implications of the Second Law of Thermodynamics for assumptions that continuous economic growth is possible because depleting resources will always be substituted through operation of the price mechanism has been discussed by Georgescu-Roegen (1971, 1975). However the argument that there always has been and so will be a 'technological fix' for resource problems, so that science and technology can be confidently expected to come up with an unlimited energy source which does not have the uncertainty of nuclear fusion, the cost problems of solar harvesting, and the risks associated with breeder reactors cannot be refuted by logic, but the extremely high predictive ability of modern physics in relation to energy considerations means that this is a remote possibility; and it is certainly not one that should divert our attention from the highly probable future.

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* Ancillary energy production cannot however be expanded indefinitely as it adds eventually to the heat production and so heat dissipation load of the ecosphere and so increases its temperature, as the extra heat can only be dissipated by radiation to cosmic space by a higher temperature (the Stefan-Boltzmann law). This could cause major pertubation of climate and lead eventually to melting of the ice caps and inundation of vast areas of the earth. These risks are reduced by solar energy harvesting as 70–90% of the solar energy which falls on most of the earth's surface is absorbed and eventually appears as heat in any case. Using solar energy from hydroelectricity or wind or wave sources or by photosynthesis does not add to the heat dissipation load of the ecosphere.

These considerations indicate that while the most immediate restriction on expenditure of energy by man will be supply and cost, in the long run the choice will be between continued expansion of energy use at least from non-solar sources and risking disaster for future generations.

In agriculture ancillary energy is expended in the manufacture of metals, tools, machinery, fuel, fertilizers and agricultural chemicals and in the human and animal labour and fuel used in clearing, cultivating, sowing, harvesting, animal husbandry, etc., and in producing and disseminating information by research, education and extension. All of these activities can be conceptualized as energy expenditures directed at increasing the efficiency of conversion of solar energy to economic products such as food. Some of this food in turn provides ancillary energy for agriculture in human labour.

Food production will not be directly limited by restricted supplies of ancillary energy in the next few decades, even with the populations in prospect. The developed countries which use the greatest amount of ancillary energy only use a small proportion of it in their food systems, some 12 percent of consumption in the U.S.A. (Hirst, 1974), but there will be a choice as energy supplies become restricted between diverting it to food production or maintaining other major energy expenditures such as private transport and heating and cooling of buildings. There will also be a diminishing return to increased inputs of ancillary energy into agriculture as crop production is extended into lower quality soils and poorer environments. Factors other than ancillary energy will of course affect the capacity of the earth to produce the food: the cumulative effects of soil erosion of crop lands, and over-grazing leading to bush and desert encroachment of rangelands; flooding of crop lands due to deforestation; declining availability of good dam sites and the inevitable silting up of existing dams, salination and falling water tables in tube wells which increase the energy cost of pumping (see Brown, 1975).

However in the long term ancillary energy supplies and costs will be a major determinant of food production capacity and costs. For this reason a logical basis for comparing the efficiency of different forms of agricultural production including plants in comparison with animals is the output of food energy per unit of ancillary energy.* This has been termed the energy quotient (McClymont, 1973) or energy ratio (Slesser, 1973). Such values must vary widely for different situations, and of course they are an over-simplification from the point of view of comparisons of "efficiency". (For example they ignore the soil erosion per unit of food energy produced, which is much greater with grainfed compared to grazed animals than crops.) What are probably representative figures for energy quotients are shown in Table I.

Table 1

Energy quotients (production only) (output of food energy per unit input of ancillary energy in production process)

RICE – Undeveloped Countries	10–36
RICE – Intensive	7
POTATOES	2–6
OATS	7
CORN	3–5
SOYBEANS	1.5–3
ALGAE	1.2
OCEAN FISH	0.1–4
MILK	1
EGGS	0.4
BEEF – Grazing	0.3–5
BEEF – Feedlot	0.1
PETRO-PROTEIN	0.15

(Adapted from Slesser, 1973)

They indicate lower efficiencies of intensively fed animals for milk, eggs and beef compared to grazing animals, an overlap in efficiency between grazing animals and crop production, and close values for milk and soybeans. The high efficiency of agriculture in less developed countries is also evident; and most of this ancillary energy comes from human and animal labour and so from the sun and does not deplete energy resources. The figures also show a low efficiency of production of food from algal culture and fermentation of petroleum by-products, disposing of the idea that these sources would make a major contribution to future food supplies. The contribution of the latter would in any case be limited by depletion of fossil fuels. However the major energy cost of food as consumed is not in producing it but in transport, processing, packaging, retailing, shopping, home storage and cooking. This is 6–9 times that used in production (Gifford and Millington, 1973; Hirst, 1974). When this energy is taken into account processed fruits and vegetables have the lowest efficiency, fresh fruit and animal products are moderately efficient, cereal products are next most efficient and sugar, fats and oils most efficient (Table 2.). As sources of protein all basic foods have shown a similar order of efficiency (Hirst, 1974). It is evident then that general condemnation of animal production as 'energetically inefficient' compared to plants is invalid.

As great numbers of people are affected by energy deficiency it is immoral or unethical to feed grain to animals. It is often pointed out that the average person in a developed country uses about 1 000 kg of grain per year,

*For the same reason ancillary energy can be used as an integrating measure in other fields. As put by Gilliland (1975) as a sub-title to his paper *Energy Analysis and Public Policy*, "The energy unit measures environmental consequences, economic costs, material needs, and resource exploitation." Although it has limitations as discussed by Huettner (1976).

Table 2

Energy quotients (total) (Energy in product per unit input of ancillary for production, distribution, processing & storage)

SUGAR, FATS & OILS	0.40
FLOUR & CEREALS	0.25
FRESH VEGETABLES	0.20
DAIRY PRODUCTS	0.13
MEAT & EGGS	0.10
FRESH FRUIT	0.09
PROCESSED FRUIT & VEGETABLES	0.06

(Adapted from Hirst, 1974)

mostly indirectly through animals, compared to less than 200 kg in less developed countries, and that if this grain were diverted from animal feeding to these countries it would overnight solve their nutritional problems. It can therefore be held that feeding animals on grain is unethical or immoral. *But selective condemnation of animal production on these grounds is spurious.* Grain-fed animals are only one indicator, although a very emotive one, of the great disparity in economic standards in general and ancillary and food energy consumption in particular, between developed and less developed countries. If it is unethical to feed grain to animals it is just as unethical to graze them on fertilized pastures, produce or consume canned fruit, wine, beer, tea or coffee, produce tobacco and smoke cigarettes, feed pets on canned food, drive a car for pleasure, and in general condone or stimulate a high consumption, overpackaging, built-in obsolescence economy; for all these activities use ancillary energy in the form of fuel, materials and labour which theoretically "could" be directed to producing food for less developed countries. To question the ethics of grain feeding of animals is to question the ethics of virtually everything in developed economies.

However it must be recognised that disparities in standards of living between developed and less developed countries are paralleled by equal disparities between sectors of society in both types of countries, and which are greater in the less developed. The whole historical process of "development", of agriculture, urbanization, and industrialization, has essentially been a process of development of systems of production of goods and services for meeting man's needs, and systems of allocation of the products which we call economies. This process has been characterized by a tendency to a self-maintaining inequality of allocation of products between countries and within countries. (See Brookfield, 1975). Within countries it has been the basis of conflict between "haves", with the physical or political and economic power to retain their privileged position, and "have-nots" and "haves" convinced on moral grounds or *realpolitik* that there must be more equality of distribution. Most tensions and violence within countries are basically due to this conflict; and the longer the power elite of a country retain an excessive proportion of the products, justifying themselves on the principle that might is right or myths of class or racial superiority, then the greater the eventual violence; as witness the French and Russian revolutions and uprisings against colonial regimes which failed to learn the lessons of history.

The fundamental issue posed by the theme of this Conference is then not one of feeding grain to animals in a grain hungry world but the whole issue of the allocation of products between man, or the competition between man and man for limited resources – hence my sub-title in this written version of my paper. It could appropriately be said that "we have met the enemy – and the enemy is us."

The issue in turn becomes whether, and if so how, to try and achieve more equality of distribution of products between and within countries. 'Whether' is a matter of individual and national humanitarian conscience and national politics. As to 'how', reducing intensive animal production in developed countries and directing the grain saved to the less developed countries, even if economically and politically possible, would not be logistically practicable as transport systems could not cope with the load; 70 percent of the food in less developed countries is consumed within 20 km of where it is produced. Large scale food aid can also worsen the situation of developing countries by depressing grain prices, and so production, and increasing dependence on the developed world. There is also substance in the view that food aid can itself be unethical if it compounds the problem of the population exceeding the capacity of the country to support it. What has been called the *triage* view (based on the policy of the French in World War I that wounded who had a chance of recovery and returning to the firing line had priority for treatment) is even being advanced, that aid should be primarily for countries which have prospects of balancing food needs and production. Another view which can have substance is that aid may only serve to prop up socio-economic structures which need to be changed if the problems of development are to be effectively tackled.

Logically pursued, the ethical argument for food transfer from the developed countries would ban import into these countries of rubber, coffee, tea, copra, sugar, etc. from the less developed countries, as it could be said that the labour, land and energy used to produce these goods "could" be used to produce food for themselves. The result would be no market for their major products so that without massive economic aid they would not be able to import fuel, fertilizer and other resources for food production and for the economic development which is essential for higher incomes and limitation of population growth (See Boserup, 1975). It would also ban aid to countries which directed any grain to animal

feeding, even though as I will show such feeding can be rational.

Irrespective of the lack of validity of selectively condemning animal production on ethical grounds and the impossibility of solving the nutritional problems of less developed countries by food transfers, what has been termed the 'ratchet' or 'addiction' principle, an aspect of the competition between man and man, will certainly operate. This is that once people are used to higher material standards of living, including increased animal products in their diet, the majority will not voluntarily reduce these standards to a significant extent. It is therefore highly improbable, despite current U.N. discussions of a "new economic order", and no matter how selfish and profligate it can be seen to be, that the democratic developed countries at least will significantly reduce resource use for the benefit of less developed countries (or even their own future generations). So that *realpolitik*, irrespective of other considerations, will ensure that grain fed animal production will not be suddenly curtailed in the developed countries.

Certainly in the next two or three decades energy consumption must fall, as the fossil fuels will not be there to sustain present and projected rates of usage and alternative sources will not be sufficiently developed to replace them. And as energy costs rise as a result of supply-demand forces and economic policies aimed at directing the available energy into most socially desirable uses, "energy economics" and "dollar economics" will converge. Agriculture, with all other sectors of the economy, will also adapt to the changing cost structure by reducing energy intensive activities such as by using more biological and integrated pest control as against chemical control, and using more human labour (see Steinhart and Steinhart, 1974); and there will be increasing discrimination on price against inherently low energy quotient foods such as products of the intensive animal industries in comparison with the extensive animal and cereal industries. But while ever the market place operates, while ever man enjoys eating animal products, and until, as seems unlikely, processed plant products sufficiently replicate the properties of animal products or man's food preferences drastically change, grain fed animal production will continue in the developed countries – along with production of other 'energetically inefficient' forms of food such as fruit.

The greatest immediate contribution the developed world can make to helping reduce the disparity in living, including nutritional, standards between their own and less developed countries is not by reducing grain fed animal production but by expanded trade on equitable terms, cash gifts, and technical assistance. In the long run the greatest contribution will be reducing their rate of consumption of non-renewable resources so that some at least of the more available of these resources are there to be drawn by the presently less developed countries as they develop – and by their own future generations.

But the disparities in material standards of living between developed and less developed countries and within the less developed countries cannot be solved by aid alone. The major cause of under-development and large disparities in standards of living in these countries is lack of appropriate socio-economic structures and the will to achieve rapid economic development and more even distribution of wealth. Taiwan and China, countries of very different political complexions, have shown what can be achieved. In Taiwan average net incomes have about doubled in the last twenty years and the ratio of the incomes of the top 20 percent of the community to the bottom 20 percent has narrowed from 15 to 1 to less than half of this. In many other countries the average increase has been far less and the ratio has widened. And in both Taiwan and China animal production, including grain feeding, has been a major component of their rural economic development.

Animals play no vital or irreplaceable role in the functioning of agro-ecosystems. Because of the economic advantages of specialization and mass production the last half century has seen a continuous decline in the developed countries of the mixed crop-pasture-animal farm as it evolved over the thousands of years of agriculture with its complex ecological and economic relations between its components. It has been and is still being replaced by animal-free crop or horticultural production systems and soil and plant-free intensive animal production systems. In the first the role of animals as consumers of waste and in cycling of plant nutrients is taken over by decomposers or by fire, and in the second the role of the soil-crop system in decomposing organic matter and cycling minerals from animal excreta is eliminated. These systems, provided there is sufficient inputs of ancillary energy materials, knowledge and effort for maintenance of soil fertility and for disease control, are viable. The animal is not essential for soil-plant systems, nor the soil and plant for animal systems; the animal does not itself increase soil fertility as it only excretes minerals from ingested plant matter, and there can be considerable loss of nitrogen as ammonia from urine; and grazing animals can degrade land by soil compaction and over-grazing leading to increased run-off, lower soil moisture and soil erosion.

But to regard animals purely as non-essential sources of food and as non-essential and potentially deleterious components of agriculture is to ignore the complex ecological and economic roles of animals in the functioning of farms as agro-ecosystems and in national food production and economic system:

- animals are the only economic and low ancillary energy cost means by which man can utilize the vast areas of the earth which are non-arable be-

cause of aridity, excessive rainfall, topography or soil type; because of this the grazing animal is and for the foreseeable future will be the major economic resource for millions of people in many areas of the world, both in developed and less developed countries by 'ranching', and in the latter also by nomadism and transhumance.

- animals (cattle, caraboa, sheep, goats, yaks, llamas, pigs, chickens, ducks, geese, turkeys, pigeons, rabbits, fish) play a key role in producing high value products from the vast quantities of by-products – straw, mill offals, oilseed meals, meat meal, sugar cane tops, molasses, etc. – which arise from producing human food, and which would otherwise present major disposal and pollution problems; and utilize vast quantities of otherwise valueless stubble and weeds in fallows and can play an effective role in weed control

- feeding animals grain as a supplement to diets based largely on high fibre-low energy by-products can overall increase the supply of human food; the grain increases the energy concentration of the diet and the energy intake of the animal so that a higher proportion of the energy is used for production as against maintenance, and the efficiency of conversion of the total energy in the diet can be increased sufficiently to compensate for the grain fed; so that grain feeding of animals can be indicated in even a 'grain hungry country'.

- in less developed countries plant matter on roadsides is a major resource for ruminants, and plant and animal life in irrigation ditches and rice fields a major resource for ducks

- animals can play key roles in increasing soil fertility for crops by accelerating the cycling of mineral nutrients in by-products back to the soil in a form which they are more readily available to crop plants, and in concentrating nutrients in their excreta on areas of soil for crops

- by providing an economic return from failed crops from drought or disease and rain-spoiled grain animals can significantly extend the economic cropping zone into dryer or wetter areas.

- in high rainfall tropical areas unsuited for grain crops animals can produce meat and milk from high yielding crops such as sugar cane fed with appropriate supplements.

- the pasture plant-grazing animal system in rotation with crops can improve the soil by increasing its organic matter and so its nutrient and water retention capacity and resistance to erosion, and can reduce incidence of plant disease; loss of soil structure, reduced water infiltration and holding capacity and increased susceptibility to erosion and disease are potential hazards of continuous cropping

- the legume based pasture-grazing animal system can increase soil nitrogen for crops, and the high energy cost of nitrogen fertilizers and increasing cost of energy means that this role will be of increasing importance; and increasing costs of all fertilizers and problems of pollution from intensive animal production systems and burning of crops wastes is likely to stimulate a progressive return to mixed crop-animal production systems.

- leguminous pastures can be sown and animals grazed between tree crops such as coconuts, rubber and oil palms, with potential benefit to the trees

- in the less developed world animals – cattle, buffalos or carabao, horses, donkeys, camels, yaks and llamas – are, and for the foreseeable future seem likely to remain, the major sources of power for cultivation and transport; and with increasing energy costs animal power may well start to return to the developed world

- in some countries cattle dung is a major fuel for cooking – in India it provides more energy than coal – a major construction material

- in rural areas of less developed countries animal production is often the only potential source of income other than crops; the animals are not so much a direct source of improved nutrition as an indirect one through higher incomes as part of a higher standard of living.

This last role of animals is a major justification for increasing animal production in less developed countries, not direct improvement of nutrition of the producer. Increased animal production may also be justified by the larger market and so possibly higher prices and incomes it provides for producers of grains such as corn and sorghum, by the potential for increased industrial employment in abattoirs and processing of hides and hair, and by reducing imports of animal products. However it can also lead to diversion of land from growing human food to growing grain for animals and increase in prices of grain for man because of competition from animal feeding. The basis for it being a significant source of higher income is integration of plant and animal production by straw, mill offals, vegetables wastes and if indicated purchased grain and supplements supporting the animals' excreta supporting the crops. In Asia, which produces vast quantities of pig meats largely from waste – China produces four times as much as the U.S.A. – the pig is called 'the poor man's bank'; with it he can

accumulate a cash resource additional to his crops. Goats, poultry, sheep and cattle can play similar roles.

However if government policy in less developed countries allows development large scale poultry or pig production units the scope for animal production being a significant source of improved standards of living and so nutrition in rural areas is much reduced. Large scale units compensate for the lower prices which result from increased production by high volume production and high level technology. Neither of these is open to the small scale producer and so he is likely to be forced out of the industry. The end result of government policy to increase animal production to improve nutritional standards can then be more and cheaper animal products for those able to afford them, mainly the urban elite who are already well fed, though the poorer fed urban lower income groups can benefit, but lower incomes and so poorer nutrition of the rural community. The title of Schumacher's (1973) book – "Small is Beautiful: economics as if people really mattered" is a good basis for attacking this problem. The major justification for large scale animal units in less developed countries is as a source of genetically superior sows and boars and day old chickens for supplying small holders.

The future of 'animal production in a grain hungry world'. While it is true then that animals are not essential sources of nutrients or essential components of man's agro-ecosystems, it is equally true that they can confer major benefits on man

- by producing preferred goods of high nutritional and economic value and valuable products such as hides, gelatin and insulin often largely from otherwise unused land resources or waste
- by providing higher incomes and so higher standards of living, including better nutrition, for persons in less developed countries who may have little or no alternative sources of higher income
- by improving quality of life for all through more palatable diets
- by stimulating ecological stability through pasture rotations which build up soil fertility and reduce erosion
- and by providing power.

and all without necessarily increasing the utilization of non-renewable resources of fuel, particularly where legume-based pastures reduce the need for nitrogenous fertilizers and animal power is used in place of machines. The net result is that even in the most densely populated poorest countries animals are an integral component of their agricultures and animal products a significant component of diets. It is significant that the development plans of most less developed countries include increased animal production.

The role that animals will play in the agriculture of the future will however as in the past be determined largely by the profitability for the producer and so on markets, supply and demand and costs of production. But increasingly society must take an holistic view of agricultural production systems, taking into account the total needs of man – nutritional economic and quality of life – and resource conservation, including fuel, soil, minerals and water resources. Such an holistic view must involve imaginative devising and testing of ecologically and economically valid systems. Research in progress at the University of the Philippines at Los Banos indicates the kind of creative thinking needed (Mendoza, Altamarino and Javier, 1975). A system is being devised and tested for using rows Leucena (a leguminous tree) between grain crops in small farm systems. The trees provide high protein leaf for supplementing low protein diets of crop by-products for work animals and animals being fattened for profit, nitrogen for crops via leaf fall, root transfer and animal excreta, cash income through sale of dried Leucena leafmeal for poultry and pig diets, a living fence or wood for fencing and construction, fuel for cooking, a high protein vitamin C supplement for human diets and even seeds for a cottage industry of making necklaces.

The criteria of whether or what form of animal production should be included in an agricultural system is that it improves economic returns and ecological stability as indicated by increased soil fertility and reduced plant disease, pollution and depletion of non-renewable resources of soil, energy and minerals. In relation to depletion of resources, a great part of the grain production in the developed world is for feeding to cattle because of the difficulty of sustaining high rates of growth on pastures and roughage diets and so in maintaining a consistent supply of high quality carcases. This means increased loss of soil from the erosion associated with cropping, and greater depletion of energy and mineral resources. Emerging knowledge of the nutritional limitations of pastures and roughages and how they may be overcome (Leng, 1976) gives promise of higher and more consistent rates of growth of grazing and roughage fed animals. Coupled with the higher potential rate of energy production from pastures compared to crops this gives promise of reducing the necessity for dependence on grain for producing beef, with all its resource depletion disadvantages.

However an active approach to devising ecologically and economically valid whole farm systems is conspicuously lacking in both developed and less developed countries; and this can be attributed in large part to the nature of much of our agricultural education and research. They have been primarily concerned with spe-

cialised understanding of components of the agricultural production system – the soil, crops, pastures, animals, insects, microorganisms, etc., – not to understanding of the ecology and economics of the agro-ecosystem itself, based on understanding of the interactions between these components in meeting the need for man for food, income, fuel and construction materials, and for more ecologically stable and less resource demanding systems. As a result agricultural graduates, agricultural teaching at all levels and agricultural research have all tended to be over-specialized. An approach to agricultural education and research based on principles of ecology and systems can provide a corrective to this (McClymont and McDonald, 1972).

In my opening remarks I referred to the breadth and depth of issues which the theme of the Conference raised. For this I make no apology – you chose the theme. But if my treatment of it has brought home that animal production will have a continuing and important role to play in our 'grain hungry world', the essential nature and one-ness of the problems of the world between and within countries, and the inextricable relations between economic, energetic, nutritional, ecological, political and moral issues, and the implications for each of us, then my time in preparing this paper and your time in listening to it will not have been wasted.

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