Animals as an Energy Source in Third World Agriculture

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It is now widely recognized that most development programs have not succeeded in improving the lot of the world's poorest inhabitants and that development strategies aimed at that segment of the global population should be closely scrutinized. Top priority has traditionally been given and is still being given to increasing food production by increasing output per unit of land. The technologies for doing this are well known; it is recognized that, overall, the maximum increase in food production is achieved through the modern fuel technologies. The crux of the development problem is, however, that these technologies require fuel inputs that must be purchased. The poorer landed peasants are caught in an inescapable cycle: without these fuel inputs they cannot produce more food than their own families need, and without such a surplus they cannot pay for the necessary fuel inputs.

Summary. Agricultural development programs have so far been largely unable to meet the food needs of the world's poorest. Increased food production can be achieved only from more intensive agriculture, which requires greater energy inputs per farm worker. Problems of technological infrastructure and escalating oil prices appear to preclude the spread of mechanization to Third World agriculture at this time. Efficient utilization of grazing animals in specific integrated farming systems could not only increase energy inputs through draft and transportation but also increase the yield of high-grade products and by-products from the renewable energy of biomass. An approach to development based on animal agriculture systems is suggested that might initiate a self-sustaining, more productive agriculture requiring only small inputs of fossil-fuel energy.

Is there an alternative? If an answer is to be found to guide future development rationale, it is time to evaluate carefully all available energy sources, to find their total productive capacity for a specific people interacting at a specific time with a specific land and environment. We must look closely at energy studies and models of agricultural societies available to us—not only in today's developed and semideveloped countries but also in the evolving societies of the past—to ascertain the elements of success or failure in terms of utilization of energy resources.

The strategies that man has developed for obtaining food all involve conversion of solar energy to food energy in one form or another: hunting and gathering, nomadic herding, shifting agriculture, and settled intensive agriculture with hand, animal, or fuel technology. Hunting, nomadic herding, and shifting agriculture provide food with the minimum of human labor; they are indeed the most energy-efficient systems, as shown by Steinhart and Steinhart (*1*), requiring only .05 to .10 calorie of energy to produce a calorie of food energy. On the other hand, although these systems require relatively low energy inputs, they depend upon extensive areas of land per capita. Historically, they have been the choice so long as land was not a constraint, but in the long run, with population growth, the evolution of food production has been always toward more intensive agriculture—a result, as Boserup (*2*) shows, of pressure from density and land scarcity on accustomed resources.

Examples of this phenomenon today can be seen in Third World areas. In sections of South America, tropical Africa, and Indonesia shifting agriculture is still common, but population increases and land constraints are rapidly forcing a change to conventional cropping; in Africa the nomadic and pastoral societies are vanishing as they are squeezed by increasing conversion of the best grazing lands to crop production and by the increase of population and livestock due to better medical and health practices. Along with this change from shifting agriculture to continuous cropping have come a decline in soil fertility, a decrease in yields, and an increase in labor demand per unit of food produced.

In its most basic form food production is dependent upon solar energy and photosynthesis, but to intensify the production man has had to develop technology that adds subsidies to solar energy. Thus human, animal, and fuel labor became substitutes for land as the means of converting solar to food energy.

It is generally conceded that the fuel-intensive system may be the only overall, long-term solution for development, given increased population pressure and land constraints. Thorough mobilization of labor in China has resulted in labor input per hectare three to four times that of India or Pakistan; even so, there has been only a modest increase in per capita food production. The apparent change in development policy by the Chinese government, then, would seem to reflect a recognition that food production can be further expanded only by adopting modern forms of high technology with its attendant energy demands. However, experience in many Third World countries shows that the jump from classical shifting agriculture to intensive fuel-based agriculture is not practicable. In addition to the cost of purchased fuel, there are the problems of machinery purchase, of sustaining a technology base for machinery maintenance, and of meeting complex marketing and institutional requisites. Thus for the near term it appears that solutions must somehow be found in the context of a middle system of animal agriculture.

Efficiency of Animal Agriculture

In recent years, several studies have addressed the question of energy use for agriculture in the Third World, and comparisons of energy use have been drawn between subsistence farmers in the Third World using hand and draft-animal labor and the commercial agriculture of developed countries. It has been well demonstrated that the use of draft animals decreases the basic energy efficiency for food production; Pimentel (*3*) documents this fact in his world energy budgets, some of which are summarized in Table 1. These data indicate that people depen-

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dent only on hand labor have the highest efficiency of energy and that the use of draft animals reduces this energy efficiency to the level found in the agriculture of the industrialized countries, or lower. Food production by hand labor in Congo, Sudan, and Mexico is estimated to require .03 to .10 calorie of energy per calorie of food produced. Introduction of draft animals raises the energy subsidy to .30 for corn in Mexico and rice in the Philippines and to 1.05 and 1.10 for grain production in India and Nigeria, respectively. Reported differences between countries are almost entirely due to differing estimates of the amount of energy draft animals require. The same conclusion can be drawn from comparison in Table 2 of China and India derived from another data base, with India dependent on animal labor and China on human labor.

Table. 1. Energy inputs and food energy production of various areas of the world (megacalories per hectare). [Data from (*3*)]

Description	Input	Output	Energy subsidy (input/output)
Congo, hand labor, cassava	572	21,450	0.03
Sudan, hand labor, sorghum	210	2,970	0.07
Mexico, hand labor, corn	676	6,843	0.10
Mexico, oxen, corn	979	3,312	0.30
Philippines, buffalo, rice	1,831	6,004	0.30
India, oxen, wheat	2,838	2,709	1.05
Nigeria, oxen, sorghum	2,722	2,472	1.10

Odend'hal (*4*) estimates that bullocks, which are estimated to supply 62 percent of the energy for Indian agriculture (*5*), use their feed with an efficiency of only 4 percent for draft. However, the overall efficiency of Indian cattle is increased to 17 percent when the energy value of dung is included, and would increase still further with contribution from milk and by-products (*6*). Nomadic livestock are very inefficient by these calculations, that is, their output per animal unit is smaller. The data of Ellis *et al.* (*7*) indicate an energy input of 165 calories per calorie of food output in the forms of blood, milk, and meat for a pastoral group in Uganda. They compare this with 18 calories for range cattle in Colorado and 15 calories per calorie output of food and dung for fuel calculated from the data of Odend'hal.

Differences between agricultural systems can be shown more specifically with data on rice production presented by Makhijani and Poole (*8*). Although energy inputs are estimated to be quite similar in five countries (Table 2), the rice yields vary up to fourfold according to the primary source of energy, which consists of human labor in China, draft animals in India, small-scale power equipment in Taiwan and Japan, and large-scale equipment in the United States.

Estimated energy inputs are lowest for India, but the combination of very low yields and the feed requirements of draft animals results in the lowest efficiency. Intensive human labor systems practiced in China result in higher yields and higher efficiency. Mechanization requiring fossil fuel, whether in Taiwan, Japan, or the United States, increases the energy efficiency of rice production almost twofold. This calculation for the energy efficiency of rice production is essentially the same as that of Pimentel *et al.* (*9*) for U.S. corn production.

The difficulty with these comparisons of energy efficiency is that the energy inputs are qualitatively very different and differ greatly in economic value. They are therefore a fallible criterion for deciding what is the best form of energy input in a given set of conditions. Mechanization that requires nonrenewable fossil fuels calls for cash outlays as well as capital for the associated machinery together with an entire technological infrastructure. Human and animal labor are fueled by renewable energy sources through photosynthesis and are in this way available to the people on the land at no cash outlay. The lower operating cost of mechanized agriculture must be plotted against this fact.

Nevertheless, computation of energy efficiency is a useful means of comparing the world's agricultural systems. Development means the command of more energy per capita. Reliance on human labor as the sole energy input cannot achieve this on an overall basis. Output per worker in nonmechanized crop production systems is limited by heavy labor demands for short periods at planting and harvesting in the areas where additional crops, or at least additional traditional crops, cannot be managed. Even for a rapidly developing country like Taiwan, it is estimated that 28 percent of the year's farm labor is required during a period of 30 days. The size of family needed to meet this demand for labor for short periods during the year creates heavy demands throughout the year on the food produced (*8*). Furthermore, food supplies may thus be insufficient to sustain the energy needed for optimal work; this possibility has been explored recently by Seckler (*10*).

Draft animals, on the other hand, when their potential is fully used, can provide not only the vital energy supplement for agricultural production and transport but also food products and the means of year-round income for the farmer. The reduced energy efficiency of food production because of animal feed demands need not be a major constraint if their feed can be produced without serious competition for the human food supply or the resources to produce it. Gasoline is a nonrenewable resource rapidly escalating in price, whereas fuel for draft animals can be produced from free solar energy, requiring in turn, however, land, labor, water, and fertilizer. Development programs must address themselves to the questions of providing these requirements for animal agriculture systems and maximizing their total production capacities for individual Third World countries. For that purpose, a look at the qualities of successfully operating animal systems outside the Third World, past and present, is a good starting point.

Preindustrial Models

Today's developed countries in their preindustrial stage had, like the Third World countries, an agriculture dependent upon renewable energy sources from the sun. That agriculture, moreover, is generally acknowledged to have provided the food and income surplus that made possible the Industrial Revolution and thus provides a pertinent model for analysis (*11*).

> Our present labor-saving technology is rooted in a peasant society which had already [in the Middle Ages] learned to apply new implements, new animal power and new management systems of the soil.

It would be important to determine whether the farmers of preindustrial Northern Europe commanded more solar energy per worker than today's farmers in the Third World. If so, are there lessons that can be applied to today's problems of world food production?

Agriculture in Northwestern Europe developed in the Middle Ages to exploit an environment in a humid forested region that had not been exploited by any previous society or civilization. This society, as it developed over the early centuries, put more dependence than other

Table 2. Energy use per hectare for rice production in various countries. Rice is assumed to contain 3500 kcal/kg. [Data calculated from (*8*)]

Location	Energy input (Mcal/ha)	Yield (kg/ha)	Output (Mcal/ha)	Energy subsidy (input/output)
India	6,678	1,400	4,900	1.36
China	8,064	3,000	10,500	0.77
Taiwan	8,064	4,000	14,000	0.58
Japan	8,820	5,600	19,600	0.45
United States	8,064	5,100	17,850	0.45

societies did upon draft animals: first oxen and then, in the richer farming areas, horses that could perform 50 percent more work than oxen (*12*). More and larger draft animals were possible in this region because more forage was available. Three-course rotation, made possible by greater summer rainfall, provided spring crops such as oats, a high-quality feed necessary for working horses. Later the agriculture of Northern Europe became more intensive; clover and root crops, introduced to replace alternate years of fallow, contributed to soil fertility as well as providing feed for livestock.

The environment of Northern Europe, with its humid climate and fertile soil, provided forage with only minimal competition with cereals, the basis of the human diet. Hay harvesting had the advantage that its timing did not seriously interfere with cereal production; thus it obviated the problem of seasonal underemployment associated with production limited to a single food crop.

Improvements in forage production made possible by the three-course system of Northern Europe resulted not only in an increase in draft animals but also in increased yields of milk and meat, products of greater value than grains. In addition, the animal products were less sensitive to economic cycles (*12*); small farmers wholly dependent upon grain sales are often in the position of having surplus grain for sale only in good crop years, when prices tend to be low, and being forced to buy grain for their families when crops are poor and prices high. Three-course agriculture provided the family grain as well as marketable animal products, and the ability to support more livestock also meant that more manure was available to replace fertility lost through cropping. The reason that this could be maximized for this society was that the environment of Northern Europe provided an abundance of wood, not an inconsiderable factor for farmers, because in regions short of wood poor peasants must burn cattle manure, with the consequent loss of fertilizer, especially nitrogen. It is estimated that in Pakistan and India 50 to 60 percent of the manure is used for fuel (*13*).

Thus, through the use of grazing animals the average farm worker of preindustrial Western Europe had at his command more energy than peasants had ever had before. Solar-energy processing through grazing animals in turn provided him with more than his contemporaries in other areas of the world had of (i) draft power, (ii) valuable animal products and by-products for year-round income, (iii) protein of high quality, and (iv) fertilizer. In the 12th and 13th centuries Western peasants may have been no better off than those of India or China, but they probably were better off in the 15th and 16th centuries, while the dominant power of Western countries became apparent to the world in the 16th and 17th centuries.

Table 3. Cattle population and productivity. [Data from (*24*)]

Region	Number (millions)	Slaughtered (%)	Carcass meat per head (kg)	Cows milked (%)	Milk yield per cow (kg)
North America	130	37	95	11	480
Middle America	39	15	26	13	124
South America	190	16	32	11	105
Western Europe	89	36	77	38	1289
Eastern Europe	35	34	56	46	1090
Soviet Union	102	36	60	40	807
China	63	15	24	10	53
North Africa–Middle East	44	18	20	27	174
Central Africa	116	8	9	12	33
Southern Africa	16	19	34	11	194
India	179	1	1	10	45
Southern and Southeast Asia	75	10	12	10	37
Japan	4	36	95	31	1373
Oceania	37	31	53	36	361
Rest of world	11	17	27	14	112
World	1130	19	37	17	329

An important characteristic of energy-intensive agriculture is that with increased productivity the arable land area declines because inputs are concentrated on the most fertile land. Poorer peasants who cannot obtain the inputs to increase yields and must depend primarily on their labor are forced to cultivate more land and land that is increasingly less productive and more erodable. The resulting soil erosion is reaching disastrous proportions worldwide (*14*).

Postan (*15*) interestingly remarked on a similar situation in 14th-century Europe, a trend that was reversed as a result of depopulation following the Black Death (*15*):

> Population was abundant and growing, land was scarce and getting scarcer and men in search of sustenance were forced to till the lands which in other more spacious periods would and should have been used as pasture, and in fact were so used again from the 14th century onwards.

Thus the opportunity of more energy-intensive agriculture to reduce the requirement for arable land under controlled population conditions has important consequences for livestock production, because the less fertile land released from cropping usually provides forage.

As successful mixed crop and livestock farming became the basis of English farming, it was a model that was exported with its emigrants to new lands in America and Australia, where forage for livestock was abundant. Likewise, certain Swiss-German emigrants, settling in preindustrial America as the Amish and continuing to the present day as a society practicing draft-animal agriculture, also provide a reasonable model of mixed agriculture and lessons for the Third World. Unlike the situation in the Third World countries today, energy inputs per calorie of food are lower in Amish agriculture than in the agriculture of mechanized neighbors (*16*). The Amish, however, are a small, strongly work-oriented society existing within the larger highly technological society; they utilize to varying extents current scientific information and farming methods and depend upon established markets to sell their produce. Although their incomes are lower, their lower consumption results in higher savings. In the past, population pressure from large family size has been relieved by migration and purchase of additional fertile farmland with savings; when these alternatives are no longer available, the Amish will face the option of practicing population control or leaving the land and seeking other means of livelihood in the larger society. That they are already taking up the latter option is evidenced by the number of their young people leaving for the cities and the increase of Amish small-town dwellers in nonfarming but supportive trades (*17*).

If we summarize the qualities of these model animal systems found outside the Third World, then, we find a combination of unique and general characteristics. Those unique to time, people, place, and climate which produce an internally evolved system of animal agriculture are presumably not directly applicable to Third World development. The concept is, however, important to indicate what must be the guiding rationale of development strategy: a successful system for any society needs to be the result of internal evolution over time of a specific people interacting with specific factors in a specific environment. The general characteristics of a successful animal system are clearly present in the models to be applied to such a strategy: (i) multiple cropping to maximize labor resources and produce forage; (ii) a specific system of land use, in conjunction with population control, to accomplish intensive cropping of fertile land and forage production on less fertile land; (iii) maximized use of animals for draft, transportation, food, and by-products; and (iv) use of manure as fertilizer, other fuel resources being made available.

Animals in the Third World

Developing countries have large numbers of cattle, buffalo, sheep, and goats; some 55 percent of all the world's cattle are found in the tropics of the Third World, as are 60 percent of the world's buffalo (these mainly in Asia). Livestock play a vital role in the lives of hundreds of millions of people. They supply not only meat, milk, and by-products as they do in the industrialized world but also 85 percent of the draft power used in the world's agriculture; in places such as India and Pakistan, 40 to 60 percent of all goods taken to market are transported by camels, donkeys, buffalo, and oxen (*13*). In many areas the smaller farmers and the landless are especially dependent on their livestock. For pastoral societies livestock are also symbols of wealth and prestige and serve for payment of a bride price, for inheritance purposes, as insurance against harvest failure or catastrophic drought, and as a source of easily cashable investment capital.

Third World livestock owners are currently facing serious problems from population pressures and land constraints, and the time is critical for development strategy to incorporate the animal factor. Until recently agricultural development projects have concentrated on improvement of crops and crop production, on the premise that the lower on the food chain people are fed the more efficient the operation; Third World governments, in addition, have had an urban bias and have been more receptive to a focus on cash crops. Ruminants do require nearly 20 pounds of plant protein to produce 1 pound of animal protein; but the latter generally is of greatly superior quality for human nutrition, and the strategies to date have ignored both the tremendous contributions already being made by animals and the important fact that much of the world's land is too steep or too wet or too dry or too cold to produce human food crops but can frequently be harvested by ruminants, which are not then in competition with mankind for the arable land.

Production of most livestock in the developing world is far below its potential, as shown by the comparative figures in Table 3. For example, the annual "offtake rate" (yield) for cattle herds in Africa averages about 3 percent compared with some 35 to 40 percent in North America; milk production in Southeast Asia is estimated at 37 kilograms compared with 480 kg in North America (where over 80 percent of the cows are of beef breeds with relatively low lactation rates) and 1289 kg in Western Europe (which has a much higher percentage of dairy cows and fewer specialized beef cattle), and 1373 kg in Japan. The principal constraint is the quantity and quality of feed. Because of their specially adapted stomachs and the synergistic role of microbes, which permit digestion of coarse, fibrous feeds, ruminant animals can exist for long periods on forage of low quality. But digestion rates are slow, and ruminants are unable to compensate for the low quality of feed by eating more, even when it is available; in fact, the reverse is true, and the poorer the feed the less is consumed (*6*). The feed requirement merely to maintain an animal is a high percentage of the total intake, and for this reason the marginal efficiency of feed use is much higher than the average efficiency, especially for ruminants. In many cases feeds of poor quality will not even support maintenance, and as a result body reserves are used until more favorable climatic conditions recur, at which time reserves can be replaced. Thus large seasonal changes in body weight are a common feature of livestock in the developing countries, especially those in the tropics or subtropics. Here they must contend with a climatic situation where either rainfall is abundant and temperatures are high, causing plants to grow so rapidly that the forages are much less nutritious than in the humid temperate zone (*18*), or there is a deficiency of soil moisture, as in the semiarid Sahel regions. Because of the escalating demands on the land for human food, livestock frequently depend upon scavenging what people cannot or will not eat. Even where land is available for forage production, its quality tends to be low because the focus is on food and cash crops. In the fertile highlands of Kenya, such emphasis is being placed on coffee and tea in an era of high profitability of these crops that policy-makers fear there may soon be food shortages in that country.

Next to inadequacies of feed, cultural patterns are the most serious obstacles to livestock development. Because of the multiple uses of livestock, many of them unrelated to productivity, numbers are prized over economic productivity. Owners keep large numbers of animals which they are unable to feed adequately, and the condition of many animals is little short of what would be considered criminal in North America. Animals in poor condition are prime targets for parasites and disease, and despite the vast strides made in veterinary care the health status of millions of animals remains alarmingly low.

Weak animals are less efficient purveyors of draft power, of course. As was noted in relation to Table 1, there is a shortage of reliable statistics on the current use and efficiency of animals for draft purposes. Ramaswamy (*19*) estimates that in India two-thirds of the energy input to agriculture is derived from animals, though not nearly as intensely and efficiently as could be.

Thus, although large numbers of animals are present in the Third World and their vital importance is evident, the crucial question is how to realize their full potential for food products, by-products, power, and fertilizer, a question which is still unanswered after many years of experience with development programs.

Animal Agriculture Systems as Development Strategy

Third World development ultimately depends on the ability of the masses of the rural poor to earn disposable income and thereby enter the mainstream of the national and international economy. What is required in this age of escalating costs of fuel energy, expanding populations, and concern for the environment is a substantial reorientation away from the philosophy that mechanization utilizing fossil fuels is the development strategy of choice, and toward a reallocation of resources into animal systems. Animals, fueled by renewable solar energy, provide the power for production and transport, as well as meat, milk, and blood (as consumed routinely by nomads) and the by-products hides, wool, hair, bones, and so on. Animals can also help to balance income and production over the entire year and to equalize seasonal labor demands. In total they can provide the means for Third World farmers to capitalize on the other resources that they have in abundance: solar energy and underemployed labor.

To make an animal system possible, the nutritional constraint in the tropics requires for the Third World the equivalent of the turnips and clover that revolutionized agriculture in Flanders and England. Given the finite supply of land, the solution lies in more intensive use of existing arable land. Some prototypes exist; cassava is a high-yielding plant under cultivation in the tropics, and sugarcane is being used as a basis for animal economies in several tropical countries, as described by Preston (*20*). A derinding machine that removes the poorly digested fraction of sugarcane and produces a feed that supports milk production and fattening of cattle is discussed by Donefur (*21*); Preston believes similar results can be obtained without derinding. To provide the needed supplementation as well as improve soil fertility, multiple cropping can be applied to produce forages, especially legumes which fix nitrogen. Other crops now being used for this purpose include berseem in Egypt, and *Stylosanthes* grasses in tropical Africa, introduced after successful experiences in Australia.

The entire question of multiple cropping needs renewed emphasis in development programs, especially with crops of use as animal feeds. Techniques in interrow planting, for example, underplanting of forage crops among tree crops, have been successfully employed in several areas of the world (*22*); pastures too can be established among tree crops where livestock are available to graze them. Greenland (*22*) cites data from the International Institute of Tropical Agriculture showing increases of over 100 percent in total production when maize was intercropped with cowpeas, compared to cowpeas raised alone, with any of four different methods of tillage, including zero tillage, which interestingly gave the highest yield of the four. In addition to the higher yields obtained, there is an increase in nutritional value from the diversity of crops. There are other significant advantages in multiple cropping: First, there is the added protection against erosion, especially in the system of relay cropping (deriving several crops in the same growing season). Second, it calls for additional labor as the principal input, which, as mentioned earlier, is readily available and currently greatly underemployed. Finally, additional fertilizer would be provided by the better-fed animal populations, especially where wood crops are increased or methane is realized from the manure (*23*) to provide heating and cooking fuel while the use of the manure for fertilizer is retained; the eucalyptus tree, introduced into Ethiopia from Australia many years ago, already provides a continuous supply of fuel for much of the cooking, and rapidly regenerates itself after harvest.

The cultural dimension of the animal system is scarcely less important than the nutrition of the animals, and indeed can be an integral cause of the undernutrition, as when priority given to animal numbers leads to overgrazing. The system of land tenure in many developing countries must be reorganized; the difficulty of accomplishing this, however, cannot be lightly discounted. Reorientation of governmental officials and planners toward greater emphasis on animals must be part of the strategy and the system, as well as a program of training for the research personnel, the technicians, the extension workers, the livestock producers, and the agriculturalists. Introduction of appropriate technology, such as irrigation techniques using animal power, and pesticides to improve animal health, must also be considered. Other advances would stem from better design of animal collars and harness, of implements for cultivation, and of animal-drawn vehicles for transportation of goods to market (*19*). Adequate markets and marketing systems are of course a mandate for development, in this context as in any other.

All proposals must take cognizance of the particular circumstances of each country and be adapted to the specific physical and cultural environment, as well as to the existing systems of agriculture, which generally have evolved over long periods in response to a unique set of conditions; in other words, each program must be specific to a country. Efforts in this direction have recently been initiated by the Centro Internacional de Agricultura Tropicale (CIAT) and by the International Livestock Center for Africa (ILCA), which has since its inception been dedicated to the systems-approach integrating production, sociology, economics, environment, documentation, and training.

Foreign assistance programs are being reevaluated to determine the most effective means of increasing food production by the world's poorest. With existing land constraints, human labor alone cannot provide the energy necessary overall to lift people out of poverty. It is also apparent that small Third World farmers will not soon be able to buy oil or create the necessary technological and cultural bases to support mechanized agriculture. It is thus crucial to adopt a new guiding rationale for these programs and reorient efforts toward a soundly based animal agriculture. The solar energy, human labor, and livestock are there. With reallocation of resources, or modest initial infusions of energy-intensive aid for needed adjuncts such as fertilizers, pesticides, and irrigation engineering, such development programs could well become self-sustaining and allow for natural Third World economic evolution. Under these conditions citizen support in affluent nations might again be mobilized for the development effort.

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