Proc. Indian natn. Sci. Acad. **B52** No. 5 pp 695–702 (1986)

PROFESSOR B D TILAK LECTURE, 1985
Biomass and Rural Development

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(Delivered 13 January 1986)

Introduction

Any discussion of rural development is based, either consciously or unconsciously, explicitly or implicitly, on a viewpoint on rural development. It is best, therefore, to preface the present exposition with the viewpoint on rural development that underlies it.

A major handicap in such a discussion is the shibboleth that development can be equated with growth, and that as a corollary, growth maximization should be the objective of development.

The experience of developing countries points in another direction. Growth maximization has only led to greater polarization into "dual" societies because the benefits of growth have been skewed in favour of the minority elites and against the poverty-stricken majorities. The problem is that the content and structure of growth are as important as its magnitude. What goods and services are produced are as important as the quantities in which they are produced. Economic growth, therefore, is a necessary condition for development, but *not a sufficient condition.* Development must be an economically-efficient process of economic growth directed towards:

(a) *equity* through the satisfaction of basic human needs, *starting from the needs of the neediest*

(b) *environmental soundness* to make development sustainable over the long run

(c) *self-reliance* to ensure a participatory development.*

Thus, rural development should be viewed as a needs-oriented, environmentally sound, self-reliant process of economic growth. Since rural development cannot be isolated from urban development, it is obvious that the two processes must proceed symbiotically, and that urban growth must not be parasitic and at the expense of rural areas.

Biomass and rural development are inter-connected in many ways. Biomass production is essential for meeting the development needs of food (grains, vegetables, fruits), fibre for clothing, forest (non-fuel) products for shelter (lumber), clothing (rayon), health (medicines), and communication (paper). Biomass production needs energy inputs, the provision of which are vital developmental tasks. And, biomass is (and can continue to be) a major fuel source in the energy system.

Energy for Biomass Production

Biomass production is primarily a matter of agriculture (including silviculture). Traditional agriculture uses only animate energy sources (human beings and draught animals); it also depends overwhelmingly on locally available inputs. All this makes it self-reliant, but a price may have to be paid—its productivity may be too low to meet the needs of the growing population. Agriculture may have to be modernized.

Agricultural Modernization can be looked on as a process of replacing traditional inputs (implements, seeds, organic fertilizers, animate energy sources) with "modern" inputs (e.g., fertilizers, pesticides, herbicides, etc.), mechanical equipment (e.g., seed drills, sprayers, tractors, etc.), and "modern" energy sources (electricity, diesel, etc.)

Consider as an example four technologies of rain-fed rice production which is a crop of major importance: the traditional technology of rice production, and three variants of modern technology.

Traditional rain-fed rice technology does not use hybrid seeds, chemical fertilizer, pesticides, or herbicides. It does not use either transport vehicles or draught-power sources running on oil-derivatives. Instead, it relies wholly upon: (i) draught animals for land preparation, (ii) traditional seed varieties and organic fertilizer, (iii) manual transplanting, harvesting, threshing and winnowing.

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*This lecture is by way of a personal tribute to the social sense and enlightened philanthrophy which Prof. Tilak has shown through his attempt to conscientize Indian scientists and engineers regarding the exciting and inspiring tasks of rural development.

Variant 1 of modern rice technology differs from traditional technology in that it uses modern biological-chemical inputs (hybrid seeds + fertilizer + insecticide + herbicide), and mechanically driven transport vehicles.

Variant 2 of modern rice technology differs from Variant 1 by using tractors for ploughing whilst still retaining draught animals for harrowing.

Variant 3 of modern rice technology utilizes power threshers and replaces the tractors of Variant 2 with power tillers for ploughing and harrowing.

Thus far, agricultural crop production has only been analysed with a "black-box" approach, in which the inputs (land, labour, fertilizer, water, energy, etc.) to and outputs (production) from the black-box are counted. Such an approach does not facilitate an understanding of what is happening inside the "black-box". Even when energy is disaggregated, it is done sector-wise.

What is needed is the disaggregation of agricultural crop production according to operations which are the *end-uses* of agriculture. Such a disaggregated end-use approach enables the computation *operation by operation* of the human labour, animal labour, direct inanimate energy, indirect inanimate energy, fixed capital costs and paddy output for the four technologies considered above. It constitutes the "unpackaging" of the technological "black boxes" for rice production, and makes it possible to understand the labour (including animal labour), energy (direct and indirect) and costs associated with the operations of each technology. Finally, it permits an illustrative panoramic view of the overall main "first-approximation" implications of the three technologies of agricultural modernization as the higher-level outcome of aggregating the disaggregated data at the lower operations level, and thereby provides the "raw material" and data-base for the choice of technologies.

A comparison of the productivity of the various technologies shows that the "doubling" in paddy output (figure 1A) achieved by "modernization" comes primarily through the adoption of the improved seeds, fertilizer and pesticides (Variant 1)—the mechanization of ploughing (Variant 2) and other operations (Variant 3) do not produce further improvement to any significant extent.

The per hectare human labour requirement (figure 1B) actually increases with the Variant 1 of modernization because of the increased yield. Mechanized ploughing (Variant 2) with its greater efficiency only produces a slight decrease in labour requirements because of a decrease of the labour time required for ploughing (because of the significant increase in the ploughing rate). In contrast, Variant 3 has a major impact on human labour requirements, because it includes the replacement of manual threshing with power threshing. It not only drastically reduces the labour requirements for threshing but also those for the traditionally subsequent winnowing operation which is made redundant—all told, an approximately 25% reduction in the labour is traditionally required.

Variant 1 depends upon draught animals to the same extent as traditional technology and therefore shows the same animal labour requirements (figure 1C). There is a fall in the animal labour requirements only in Variant 2 where the ploughing operation is mechanized, but the requirement is "non-zero" because the harrowing operation is still carried out with animal power. Variant 3 of modern technology deals the *coup de grace* to draught animal power which is replaced not only in the ploughing but also in the harrowing operations of land preparation. As a result of draught animals being completely replaced with machines in Variant 3, the animal labour requirements become zero.

The direct energy requirements (figure 1D) are virtually "zero" in both traditional and Variant 1 technologies because neither of them involves any mechanization. But, Variant 2 shows a significant requirement because of the mechanization of the ploughing operation, and there is a dramatic additional increase in direct energy use in Variant 3 because of the further increase in the extent of mechanization.

In the case of indirect energy (figure 1E) which is the energy used in the manufacture of the inputs, all the variants of modern technology show a major increase in requirement (approximately 14 times compared with traditional technology) because of the off-farm consumption of indirect energy for the production of improved seeds, fertilizers, insecticides and pesticides. It follows that Variants 1, 2 and 3 are associated with major escalations in variable costs on account of the purchase of inputs that are intensive in indirect energy. They also involve dependence on external agencies which have to be established for the supply of seeds, fertilizers, equipment, fuels, etc., manufactured in urban industries servicing the agricultural sector.

Considering direct and indirect energy together, it is easy to see why modern agriculture is such a major energy sink compared to traditional agriculture.

Finally, figure 1F shows the variation of the fixed costs with the technologies—the introduction of mechanical equipment with Variants 2 and 3 leads to sharp increases (by factors of 2.5 and 6.3 compared to traditional technology) in these costs which do not show much of a change in going from traditional to Variant 1 technologies.

Thus, the "mechanized" technologies of rice production, viz., Variant 2 and Variant 3 (minus its power thresher) involving "mechanized" land preparation and transport do not increase the paddy output (unless by speeding-up operations they make multi-cropping possible). They arise from an impetus to replace draught

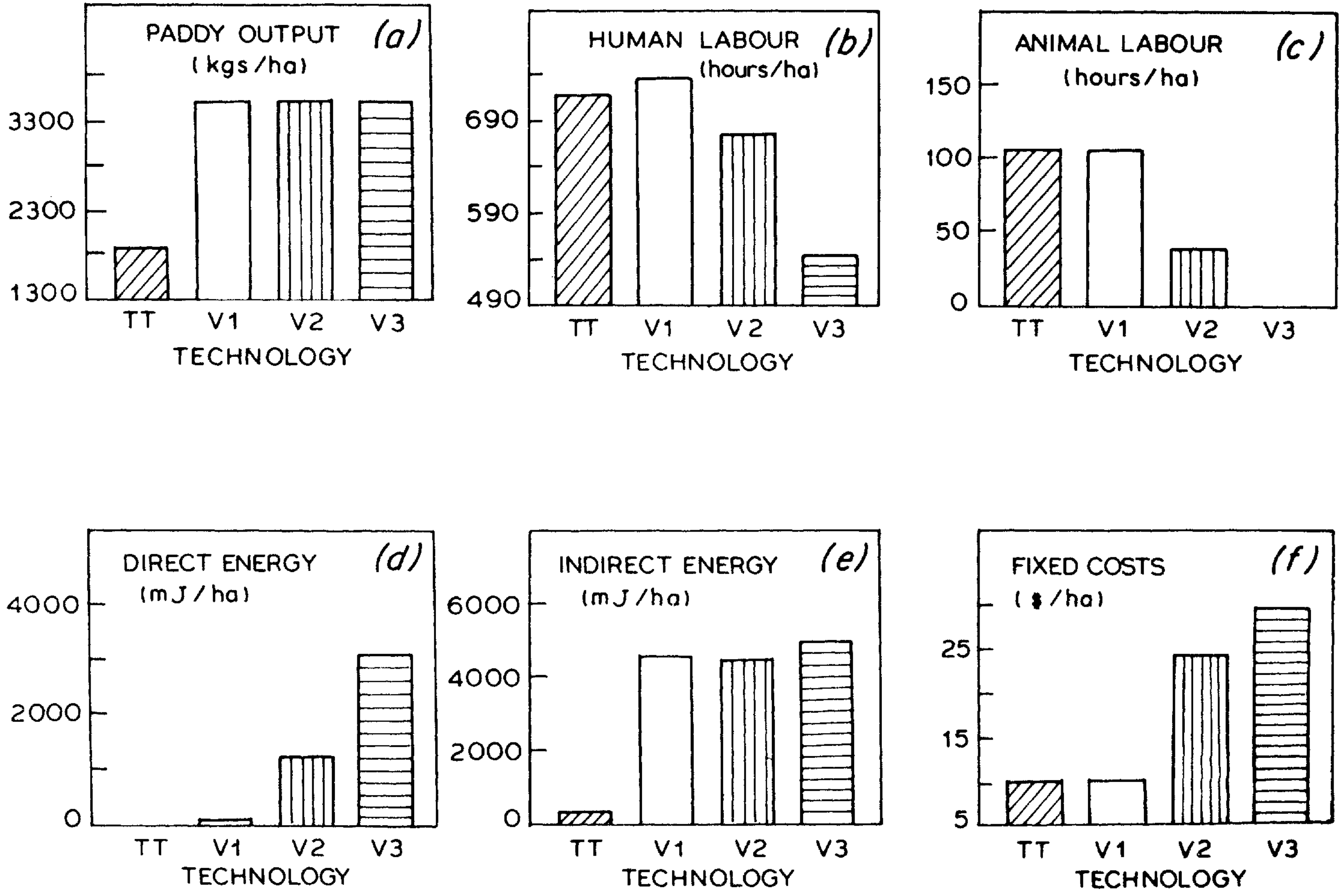

Figure 1 A comparison of the productivity of various technologies

animals with tractors and power tillers in order to overcome the constraint of draught animal power, of which there may be a shortage because of: (i) the scarcity of pasture land and fodder, or (ii) the unpleasant arduousness and drudgery of using animal power. They also eliminate the necessity of managing huge numbers of cattle and cattle-herds that would be required by large holdings because this may not be as economical as in the case of small holdings.

Variant 3 of modern technology involving the replacement of manual threshing with a power thresher leads to a significant reduction in labour requirements which must be seen against the reduction in losses in grain incurred during traditional threshing. This raises two questions:

(a) Are such labour-saving techniques introduced in pace with the rising demand for labour in urban and/or rural off-farm industry and therefore with the decreasing availability of agricultural labour? or

(b) Are they brought in because of price distortions embodied in or backed by associated subsidies, incentives, etc.?

Though the duration of a crop is largely governed by crop physiology, the overall time taken for the completion of all the crop operations can be much greater due to the time spent on land preparation, harvesting, threshing, etc. If, therefore, these operations are speeded up, and a short-duration variety is chosen, it may become feasible to go through another crop cycle within the same agricultural year. In such a case, the energy, human labour (both human and animal), capital, costs and output would have to be multiplied by as many crops as there are in a year. For instance, if variant 3 of modern technology permits *two* rice crops per year, and traditional technology only *one*, the annual labour requirement is 1090 hr/ha which is more than the 717 hr/ha of traditional technology. Hence, the comparison of technologies must be done on a *per year* basis, and not simply on a *per crop* basis.

The substitution of the traditional winnowing operation by power threshers results in a selective reduction in employment of women with all the attendent impacts on development, in general, and their incomes and status in particular. Thus, agricultural modernization can not only lead to a displacement of human labour, but there can be a gender bias in this displacement of labour by machines with women bearing the brunt of the process.

The analysis of rice production technologies has shown that agricultural modernization does not consist of a unique inflexible package which must either be accepted *in toto* or not at all. It appears that modernization could be accomplished in several stages, for example:

Stage 1: Green revolution without either tractors or machines,
Stage 2: Green revolution with tractors and power tillers,
Stage 3: Green revolution of the industrialized-country type in which virtually all the operations including harvesting, threshing, etc., are mechanized.

The discussion above has focussed a great deal of attention on energy consumption in agricultural biomass production. But, energy cannot be the sole determinant in the choice of agricultural technologies. It is only one among several other factors in the domain of decision-making, such as agricultural productivity, employment generation, investment costs and environmental degradation. In fact, the basic developmental issues to be considered in agricultural modernization include: (1) equity, (2) employment, (3) ecological impacts, and (4) energy consumption.

Nevertheless, an important issue concerns the source(s) of the energy inputs for raising agricultural production. The crucial question is whether biomass sources of energy can meet the requirement of agricultural production.

Biomass for Energy Production

The main biomass sources of energy are fuelwood, agricultural wastes, and animal wastes.

The term fuelwood covers logs, branches, twigs, roots, bark, etc., from trees, bushes, shrubs, etc., located not only in forests and woods but also along the sides of roads, tanks, fields, etc. Fuelwood is used primarily in: (i) the domestic sector (for cooking and water heating), and (ii) rural industries (brick-making, jaggery, pottery, black-smithy, etc.).

Agricultural wastes are wastes in the form of stalks, leaves, husk, etc., left after saving the grain, fibre, etc., parts of the crops. Of these, only bagasse and rice-husk are used in significant quantities as fuels, the other wastes are consumed as fodder or deployed as green manure.

Animal wastes are mainly cattle dung which is used as organic fertilizer and in the form of dried cakes as fuel.

Biomass has played and still plays a crucial role in India's national, urban and rural patterns of energy consumption.

Biomass accounts for about 55% of the total energy used in the country (9000 PJ in 1978). The total biomass consumption in this year was stated to be 295 MT with households accounting for 245 MT and industries, 50 MT. Within the domestic sector, the breakup was as follows: fuelwood, 132 MT; agricultural wastes, 41 MT; and animal wastes, 72 MT. A number of recent studies have shown that even in modern cities, fuelwood consumption is not insignificant. For example, in the city of Bangalore, the daily fuelwood consumption was about 1200 ± 50 tonnes per day corresponding to about 150 kg/capita/year.

Since the role of biomass in the urban and national settings has been discussed elsewhere, the focus here will be on biomass in rural energy consumption patterns. Even taking into account animate energy—the energy of human beings and draught animals—in computing the total energy consumption, biomass can contribute as much as about 90% of the energy used in a village.

Fuelwood is the main fuel, because on the one hand, dung cakes are, in general, used as fuel only where fuelwood is not available within a convenient distance, and on the other hand, agro-wastes are a major source of fodder. The fuelwood consumption is about 500 kg/capita/year which corresponds to about 10 kg/household/day.

Fuelwood, agro-wastes and animal wastes are referred to as non-commercial energy because they are gathered at "zero" private cost, but they are rapidly becoming commercialized. Fuelwood is gathered by women and children in the form of twigs. It is used for cooking (about 80%), water-heating and industry. Fuelwood stoves are multi-pot mud-stoves with about 8% efficiency (which becomes about 16% taking water evaporation as useful work).

Biomass has an important role to play in meeting village energy needs. In analysing this role, priority must be assigned to cooking which is the largest and most important energy consumer. There are many options for meeting cooking energy needs: (i) the present pattern of consumption (including the extremely low efficiency) could be preserved and efforts concentrated on increasing fuelwood supplies—this is the *forestry* option; (ii) The end-use efficiencies in cooking could be improved—this is the improved high-efficiency fuelwood *stoves* option; (iii) A switch could be made from fuelwood to charcoal or biogas or producer gas—this is the *alternative fuels* option; (iv) There could be a reduction of demand with conservation measures accompanied by a simultaneous enhancement of supply—this is the *demand-decrease-supply-step-up synergism* option.

The first general issue in making these choices is that of *increasing supply vs managing demand.* Just as it is invariably cheaper and quicker to save a kilowatt than to generate a kilowatt, the biomass version is that it is cheaper and quicker to save fuelwood than to grow fuelwood. However, saving alone may not be enough, and it may be imperative to exploit the demand-decrease-supply-step-up synergism.

The second issue concerns the question of *solid vs gaseous cooking fuels* noting that gaseous fuels are not only easier to light and extinguish but they facilitate quick increases of power output (for boiling) and decreases of power output (for simmering).

The third issue is whether the present practice of *solid fuel for the poor and gaseous fuel for the rich* should be permanent or temporary, i.e., whether a dual cooking-fuel energy system should consolidate a dual society or whether solid fuel should be transitional fuel to the ultimate gaseous cooking fuel(s).

The fourth issue is that of *centralized large-scale generation plus piped distribution of not-easily-liquefiable gas vs decentralized small-scale generation plus consumption*, i.e., the economies of scale vs dis-economies of organization and management.

In considering these issues, note must be taken of the recent exciting developments consisting of *doubling* of stove efficiencies and dissemination of improved stoves. Unfortunately, the poor who now use "zero-cost" stoves cannot afford the improved stoves even though they only cost Rs. 50–100—hence, these stove programmes are based on subsidies.

Stoves R & D has also led to several lessons, such as the importance of: (i) "market surveys" in the form of studies of actual cooking practices and needs; (ii) basic science, because stoves are not a trivial R & D problem; (iii) "test-marketing" in the form of user trials; and (iv) "field testing" with statistically significiant samples.

Experience has also been gained with biogas plants. Firstly, as was predicted a decade ago, family-size biogas plants have extremely limited possibilities with regard to diffusion because they are not cost-effective without massive subsidies and because only a small percentage of affluent farmers have the cattle resources to sustain the inputs to these plants. Secondly, recent experiments with community biogas plants have stressed the importance of: (i) involvement of the community, (ii) a "utility" approach, and (iii) overcoming the (dung) resource constraint associated with the low body weight of cattle in drought areas through the integration of biogas programmes with dairy development and fodder production programmes.

Lighting is an end-use which does not account for a large fraction of the total energy budget of a village, but it has a dramatic impact on the quality of life. The bulk of rural households depends on kerosene for illumination—on the average, over 80% of rural homes are unelectrified even in electrified villages. This is the case even though the kerosene lamp has a luminous efficiency which in order of magnitude is lower than the incandescent bulb which is the least efficient of the family of electric illumination devices that includes the flourescent tube. In addition, the use of kerosene for lighting involves several socioeconomic penalties that only confirm that electricity is the most appropriate energy carrier for illumination.

There are two options for obtaining the electricity to illuminate village homes: the electricity generated centrally at distant power plants can be transmitted over grids and distributed to villages—the well-known rural electrification programme—or it can be generated in a decentralized way from locally sited generating sets. There are break-even distances from the grid within which it is more economical to extend the grid to the village, and above which decentralized local generation is more sensible. Of course, the break-even distance depends upon the fuel for the local generator, and the obvious fuels are diesel, biogas and wood/producer gas. Unfortunately, a rigorous comparison between these three fuels has not been made.

Heating bath water is also an important end-use in parts of the country where the nights are cool and, therefore, it is the practice for people to use hot water for bathing. The hot water is obtained by burning wood fuel under cauldrons of water to raise its temperature to about 50–60°C.

The technological problem of heating water is quite similar to that of cooking from which, however, it differs in two important ways: (i) there is no need for the heated water to reach temperatures near the boiling point, and (ii) the volumes of water to be heated are at least an order of magnitude higher. The larger volumes to be heated, and therefore the larger energy requirements, militate against the use of biogas which is a much scarcer fuel than was once thought to be the case. The lower temperatures bring solar water-heating within the range of acceptability provided that it is done on a community-scale with hot-water distribution at a few selected public outlets so that the costs of piping hot water to individual homes is avoided. Such a community approach to solar water-heating may well involve a host of organizational problems, but the fact is that it has not yet been tried out.

In this context, it appears that fuelwood-fired water-heating stoves are the most sensible option. It may well be the case that the efficiencies of traditional *water-heating* stoves are higher than those of traditional fuelwood *cook* stoves because of the well-known efficiencies of scale of thermal reactors. Despite this, there is urgent need to draw upon the research and development experience with wood-fired cookstoves and develop improved fuel-efficient water-heating woodstoves.

In most parts of the country, agriculture is neither wholly traditional nor is it completely modernised; it is in fact passing through a transitional phase. It is characterised by dependence on draught animals and human energy and on traditional implements, but it also uses chemical fertilizer in irrigated lands as well as high-yielding varieties (HYV) on some of the farms.

Since crop productivity is highly sensitive to energy, nutrients and water, the provision of these inputs—the ingredients of agricultural modernization—is an important developmental task. Thus, agriculture needs direct energy for agricultural operations and for pumping irrigation water, and indirect energy as fertilizers.

Though draught animal power is a self-reliant, local, non-renewable source of energy, it leads to certain limitations on crop output. Thus, it has been shown that the existing draught power is inadequate for achieving timely sowing in its dry lands. This problem arises because the "ploughing window"—the period after the ploughing rains during which the soil is moist enough for the given power sources, say draught animals, to carry out the ploughing operation—is too narrow for draught animals to complete the ploughing job on the dry lands. This situation may warrant the deployment of tractors and/or power tillers (not necessarily privately owned, but for instance hired out) for the timely completion of the land preparation and sowing operations.

The inadequacy of power delivered by draught animals can also prove an obstacle to increasing the cropping intensity. When only one cycle of crop production is considered, it can be argued that mechanization is quite unnecessary unless there is a shortage of labour. Hence, in single crop areas it may be necessary to improve the efficiency of animal energy use.

If, however, the objective is to increase the cropping intensity by growing more than one crop per year, then it becomes important to consider the total time for the completion of a crop cycle. Like the crop output, this cycle time too is essentially determined by the biological factor which in this case is the rate of growth of the crop variety. When, however, short-duration crop varieties are adopted, the possibility of double, and particularly triple cropping may depend upon reducing the time taken for land preparation (ploughing, harrowing and interculture), harvesting, threshing and other operations. In such a situation, mechanization of these agricultural operations may become necessary to double or treble the cropping intensity and thereby increase crop production/ha as well as employment to process the increased output.

Another aspect of the problem of replacing draught animals with machines derives from the low efficiency with which draught animals convert their biomass fodder input into work output. If the calorific value of the fodder is considered, it turns out that the energy equivalent of the biomass input is converted into animate energy output with efficiencies as low as 4 to 7% If, on the other hand, this same biomass imput had been converted into inanimate energy through devices such as woodgas engines, the efficiency would have been much higher. In many villages, it can turn out that draught animals delivering mobile and stationary power consume every year almost as much biomass (in the form of dry fodder) as the entire amount used for cooking, water-heating and process heating. If, however, the animal power is replaced by say woodgas engines, then there is a saving of biomass to the extent of about 90% of the amount consumed by the animals.

Further, since crop residues cannot provide the fodder required for the maintenance of the draught animals, land which could otherwise have been used for growing cereals and pulses has to be diverted for the purpose to produce fodder crops or set aside for grazing. In many villages, the area devoted to fodder production is about one-third the area devoted to crops. In comparison, less than 10% of the land now used for fodder would be required to grow the wood to run woodgas engines and deliver power to accomplish the same job as the draught animals. Thus, the inefficiency of draught animals as energy-conversion "devices" also implies a low efficiency of land utilization. This is why in regions such as the Punjab in North India, where land is extremely precious, animals are being replaced by machines.

The upshot of this discussion is that, at some stage of the development process, it may become necessary to replace animal-powered agriculture with mechanical system powered by sources such as wood gas.

Energy for pumping water for irrigation is the other major energy requirement in the agricultural sector. Presently, it comes predominantly from electricity from the grid even though the transmission and distribution costs of grid electricity are highly subsidised. In addition, diesel irrigation pumpsets are also used as substitutes or as back-up equipment. It would be advantageous, however, to run pumpsets with local, self-reliant renewable sources of energy. The power requirement for lift-irrigation is characterised by peak and lean periods and the pumps are scattered over the farm-lands of the village. Wood (or charcoal) or electricity (generated in the village or nearby) are the obvious options for the energy carrier which has to be transported/transmitted to the dispersed pumpsets.

Woodgas-driven pumpsets seems to be a particularly attractive option. The wood required, assuming a 5 hP engine working for 300 hr/year, comes to 1.3 tonnes/year/pumpset. In other words, at 6 tonnes/ha/year, 0.2 ha of energy forest are required to supply the wood requirements of each pumpset in a renewable, environmentally sound and self-reliant way that also creates employment locally.

The Future Role of Biomass in Rural Development

Biomass-based energy sources and devices, therefore, are obvious candidates for the energy-utilizing activities in the developmental scenario for villages. However, before they become valid options and are included into this scenario, it must be shown quantitatively that at least the present energy needs of the village could be met from local renewable biomass resource.

Biomass can be utilized in the form of fuelwood and crop residues for heating (cooking in households and coffee-shops, heating bath water, and jaggery making), generating stationary shaft power for irrigation water and for crushing sugarcane and oilseeds, and providing mobile power (for agriculture and transport). Also, biomass in the form of cattle waste (which is now being used only for manure) can be utilized for producing biogas without losing the manurial value of the dung. This biogas in turn can run biogas engines pumping domestic water and for generating electricity via gensets for lighting. Of course, there is no sanctity to this particular pattern of usage of biomass, and innumerable other schemes can be imagined. In fact, many of them are being implemented.

Calculations of the quantitative requirements of biomass in the form of fuelwood/agro-wastes and of dung reveal several points. Firstly, it appears that locally available biomass resources provide a feasible basis for the energy component of village development. Secondly, if the new biomass schemes are based on fuel-efficient technologies, then they lead to a definite conservation of biomass resources. Thirdly, the shift to efficient new technologies results in biomass—which has been the dominant fuel in villages—assuming an even greater role in advancing current developmental needs. Finally, this enhanced role becomes possible because of the significant savings of biomass resulting from these new technologies and the diversion of these savings to new uses.

Thus, a greater role for biomass energy resources can be achieved if and only if efficient new technologies are adopted. Had traditional technologies been retained, and had the conservation of biomass resources not been there, then the supply of biomass production would have had to be increased inordinately. And these increases may stretch village ecosystems beyond their resource "limits". This demonstrates the limitations of a purely "supply approach" of persevering with inefficient traditional technologies and trying to bridge the demand-supply gap with increases in the supply of energy.

It must be stressed that the above observations must, in general, be restricted to *present* energy needs. The complexion of the problem may change drastically when the focus of discussion changes to *future* energy needs. Attempts have, therefore, been made to examine the role of biomass against a background of village energy needs in an imaginary future.

This exercise has been carried out by: (i) estimating the useful energy corresponding to the present consumption of final energy in villages, (ii) escalating this useful energy to reflect an improvement in the standard and quality of life, (iii) assuming new technologies with significant increase in the efficiency of energy use, and (iv) computing the corresponding requirements of (final) energy. The future requirements of useful energy for villages can be based on an "utopian" scenario involving major increases in the requirements of cooking, heating bath water, process heating, lighting, lift-irrigation, mobile power for farm equipment and for transport, and shaft power in industry.

The conclusion that emerges is clear: while a purely conservation approach may be adequate for present needs, it cannot sustain future requirements *unless there is also an increase in supplies*. Apart from using trees efficiently, it is also vital that there is an increase in the productivity with which trees are grown. If biomass is going to be increasingly used for meeting the energy needs of the present *and the future*, then it is imperative that biomass production must be increased which means that in a land-constrained situation—such as that in most parts of India—the biomass productivity must be increased.

It is widely believed that such a biomass productivity increase necessarily requires a change in the pattern of energy sources for agriculture (including silviculture) involving a shift to inanimate sources for various agricultural operations and to indirect energy in the form of seeds, fertilizers, pesticides, etc. Even if this shift is only partial, it means that an increase in biomass productivity hinges on energy inputs into agriculture. Thus, through the working out of its own logic, a biomass-for-energy-production strategy necessarily leads back to an energy-for-biomass-production strategy.

The Biomass-Energy Feedback Loop

The fundamental problem of *biomass and rural development* can be stated thus. Rural development necessarily means increasing production of biomass for food, fibre and forest products. But this task may be achieved with traditional biomass-production technologies which are wholly inadequate. It is essential to go in for improved biomass-production agricultural (including silvicultural), *tree-based* and/or *crop-based*, technologies.

But modern agricultural technologies in their present form give rise to several important questions pertaining to the long-term sustainability of monocultures of various species and to the ecological consequences of the chemical fertilizers and pesticides used today. Hopefully, these ecological problems will be solved through recent advances in molecular biology and genetic engineering.

Moreover, modern technologies for increasing biomass production require inputs of direct and indirect energy, and the magnitude of these energy inputs is a function of the particular variants of modern technology that are adopted. Here, it must be noted that there are variants of modern agricultural technology which when introduced prematurely impede need-oriented, environmentally sound self-reliant development. Only these development-oriented variants of modern agricultural technologies for increasing biomass production must be chosen which are compatible with other developmental objectives such as employment generation.

Thus, *energy for biomass production* means increasing agricultural production through *selective* use of inanimate energy inputs for selected operations. But, are these energy inputs available? Currently, modern agriculture depends largely on electricity for stationary equipment and oil for draught and shaft power. However, sustainable agriculture requires energy sources consistent with the developmental objectives of environmental soundness and self-reliance. What are required are sustainably produced locally available or produceable energy sources.

If the solution is *biomass for energy production*, then is there enough biomass to spare for diverting energy to the agricultural sector when there are already competing demands from the domestic and transport sectors? This question arises because, apart from increasing agricultural production, development also means increasing the provision of energy services for cooking, lighting, industry, transport. Further, biomass-based energy sources have a tremendous role to play in providing energy services at the village, city or national levels. Hence, the question becomes: is three enough land to emphasize both *energy for biomass production* as well as *biomass production for energy?*

The answer depends upon another question: *Can the biomass-energy feedback loop be closed*? i.e., can the agricultural sector produce sufficient biomass-derived energy to meet its own energy requirements even after adopting the relatively energy-intensive modern technologies for biomass production? Or, is the increased biomass output (attributable to the extra biomass-derived energy that is needed for its modern agricultural technologies) sufficient to produce the energy needs of the agricultural sector after supplying the needs of the domestic, transport, etc., sectors?

The biomass-energy feedback loop can be closed only through the establishment of a synergism between the decrease of biomass demand through efficiency improvements and a stepping-up of biomass supply. Biomass for energy necessarily means reduction of biomass-based energy demand (in the domestic, transport and agricultural sectors) through *new* technologies of utilizing biomass energy which do not jeopardize the provision of energy services. It also involves development-oriented variants of modern agricultural technologies for increasing biomass production, and *new* biomass-based energy-supply technologies for the conversion of biomass feedstocks into efficient fuels (producer gas, methanol, ethanol).

Thus, a development-oriented view leads to an approach that is based on a synergism between ENERGY FOR BIOMASS PRODUCTION for a sustainable agriculture and BIOMASS FOR ENERGY PRODUCTION for a sustainable energy system. Only such a synergism can yield SUSTAINABLE RURAL DEVELOPMENT!

Otherwise, a preoccupation with ENERGY FOR BIOMASS PRODUCTION will result in a focus on Food, Fibre and (Non-Fuel) Forest Products with Fuel being forgotten; or an emphasis on BIOMASS FOR ENERGY PRODUCTION will lead to a concentration on Fuel with Food, Fibre and Forest Products being forgotten.