Social Science Information
http://ssi.sagepub.com/

Ecotechnological productivity: a conceptual basis for the integrated management of natural resources

Enrique Leff

Social Science Information 1986 25: 681
DOI: 10.1177/053901886025003005

The online version of this article can be found at:
http://ssi.sagepub.com/content/25/3/681

Published by:
SAGE
http://www.sagepublications.com

On behalf of:
SSI
Maison des Sciences de l'Homme

Enrique Leff

Ecotechnological productivity: a conceptual basis for the integrated management of natural resources

To Ignacy Sachs

The need for a conceptual basis for an alternative strategy of development

The environmental and social problems arising from dominant economic and productive practices have become a major public concern in our time. For over a decade, the need for a new perspective on environmental planning for sustained development has been recognized, and included as one of the main issues discussed in the international arena. Some of its principles have encouraged the implementation of environmental policies by several governments.

The causes of the environmental crisis have been analysed from different ideological perspectives and from differentiated and opposing political positions, leading towards varied social and technological solutions.[1] Less successful have been the attempts at a theoretical internalization of environmental problems, a process which is necessary for understanding the historical and social determinants of the so-called crisis of resources, energetics or population growth, and for devising technological, economic and political alternatives to reverse the dominant practices of depletion of natural resources and environmental degradation.

The main efforts have consisted in trying both to internalize the "externalities" of the economic process within the paradigms of neo-classical economics and to introduce an environmental dimension into the traditional planning practices (Sachs, 1971; Gutman, 1986).

In this view, environmental policies are concerned with the conservation of nature and the control of pollution. Actions are focused on

I am grateful to Maggie Best for having corrected my English draft of this article.

Social Science Information (SAGE, London, Beverly Hills, Newbury Park and New Delhi), 25, 3 (1986), pp. 681–702

controlling the effects of current productive practices more than on preventive measures or on creating social organizations and technological patterns capable of internalizing the ecological conditions for sustained development. Environmental conservation appears as an added cost of economic growth. Thus "damage functions" are constructed to balance conventional production functions (CEPAL/PNUMA, 1984).

Several methods of assessing environmental impact have been devised, and environmental cost-benefit analysis based on these principles is being used more frequently to evaluate development projects. However, in many cases these studies are carried out after the basic technological decisions have been taken. Moreover, such projects have lacked sufficient ecological basis and scientific support (Beanlands and Duinker, 1981).

Within the dominant economic rationality, a technological solution to the environmental "externalities" of growth has been sought. Thus, research and development activities have been oriented towards creating intermediate and ecologically sound technologies adapted to the ecological conditions and the availability of productive factors in different countries, and towards designing soft or clean technologies to reduce the effects of pollution and the pressure of economic practices on the environment. Faith in technology has gone beyond its potential for discovering new resources to replace depleted ones and for promoting the exploitation of resources that were previously economically unprofitable. Ultimately, all products should be recirculated in the economic process, and raw materials would consist only of undifferentiated matter and energy (Barnett and Morse, 1963).

Such a technological dream still has to face the impossibility of reversing the laws of entropy. If the current trends in exploitation of resources, consumption habits and technological patterns continue, environmental degradation will eventually reach the ecological limits for the generation and sustained regeneration of resources. This process would inevitably also lead to the growing transformation of energy into heat, crossing certain thresholds of ecological and geophysical equilibrium and endangering the survival of the human species.

From a broader social perspective of the development process, the concept of ecodevelopment emerged as a new strategy mainly conceived for the undeveloped regions of the world. Proposed by Maurice Strong and further developed and promoted by Ignacy Sachs, after the United Nations' Conference on the Human Environment held in Stockholm in 1972, the impact of this concept was felt both at government and academic levels (probably in Latin America more than in other regions of the Third World). Linked to a concern for restructuring the world's economic

order, it proposes valorizing resources in rural areas by implementing ecotechniques adapted to the ecological and cultural conditions of each community and the technological self-reliance of the people. By developing technologies based upon the substitution of renewable for non-renewable resources and by tightening the tissue of the productive process through the use of complementary activities and the recycling of by-products and residues, the practices of ecodevelopment promote a more ecologically rational and sustainable strategy of development.

If a systematic overview of the interrelationship of population, technology and resources is taken, it is necessary to integrate the ecological and social externalities of the dominant economic rationality into the paradigms of political economy, and to insert the environmental dimension into the planning practices of governments. Thus, opposing the zero growth solution to the limits of growth, the ecodevelopment perspective has opened the way for new styles of development calling for ecological prudence and solidarity with future generations (see Sachs, 1980, 1982).

What has been missing from this perspective is stronger theoretical support for constructing an *alternative productive rationality* that could be opposed and contrasted to the ideological, scientific and technological structures that support present economic trends. The environmental crisis poses a more radical critique of the economic rationality that has become predominant in the last two centuries and calls for an alternative productive rationality that goes beyond simple preventive and remedial environmental policies.

From the perspective of underdeveloped countries, the environmental crisis raises more radical questions about its origins, and demands more complex political and theoretical processes to reverse the negative effect on the environment of current policies. A great challenge is issued by the need to generate the scientific and social changes necessary for incorporating the *environmental potential* of those countries as a *productive force* into an ecologically sustained, politically independent and technologically self-determined strategy of development.

Economic and technological dependency, the inequalities of the international economic order, and the role of underdeveloped countries in the international division of labour, have had a negative effect on the tropical regions. The high impact of pollution in these areas is due to urban and industrial concentration, to inappropriate technologies being used for the transformation of natural resources, and to the lack of governmental controls in all productive activities. Furthermore, the environmental crisis of poor countries should be assessed in the light of the historical process of overexploitation of their natural and cultural resources and labour

force. This has caused a process of ecological degradation and depletion of resources leading to a net loss of natural resources and the ecological potential for their future development.

From this perspective, *the environment* is viewed as a *productive potential for development* more than as a cost to be deducted from economic development. This potential can be assessed using the concept of *ecotechnological productivity*, understood as an overall social process of articulating ecological, technological and cultural levels of productivity leading to an integrated management of productive resources.[2] This alternative productive rationality is more than a new technological solution to the environmental crisis; it is strongly rooted in a social perspective capable of reorienting political actions and economic processes, as well as the scientific and technological potential of society, towards new options for a sustained development.

I will refer to this combination of ideological, theoretical, scientific and technological processes linked with the construction of such productive rationality as an overall social paradigm. I use Kuhn's concept metaphorically, as what this epistemic process embraces is broader, deeper and more complex than a "disciplinary matrix"; and its "exemplars" – the concrete social process where the productive rationality of such paradigms is tested – are beyond the experimental field of any scientific discipline (see Kuhn, 1962, 1977).

The environmental perspective of development does more than merely question conventional economic calculations and current technological patterns; it has actually induced a process of transformation of knowledge within different scientific disciplines and ideological formations. The environmental perspective does not prescribe scientific revolutions in any field of knowledge; but the construction of the ecotechnological rationality demands "changes of paradigms" arising from certain transformations, production and articulation of theoretical and practical knowledge (Leff, 1986).

I will now briefly characterize the capitalist productive rationality and discuss some basic theoretical elements for constructing an ecotechnological paradigm of development, and making it operational.

The dominant economic rationality

The predominant causes of the environmental crisis do not arise from an intrinsic demographic process nor from an inevitable tendency in the historical process of development to use increasing amounts of

non-renewable sources of energy. The food and energy crises, the overexploitation and depletion of resources, are the result of that economic and technological process directed by the goal of maximizing either the private profits of the capital invested or the economic surplus of the state-controlled economies. This economic process has been supported by a generalized process of capital accumulation.

Within the capitalist system, this process is governed by its structural need to increase the productivity of capital and is legitimized by the ideology of free enterprise. In the socialist camp, a certain evolutionist conception of history, giving predominance to the development of productive forces over transformations of social relations of production, favoured a rapid accumulation of capital. From these somewhat different perspectives of historical development the capitalist and socialist powers battle for economic growth as a means of attaining international political supremacy. Their scientific and technological achievements have gone beyond human imagination and are only surpassed by fears for human survival.

These economic and political conditions have guided a technological process conceived of as the overall organization for the production and application of knowledge oriented towards the accumulation of capital. This economic rationality has been supported by an economic paradigm where technology is perceived as a commodity inserted in its two basic factors of production: capital and labour. Technology is thus associated with the productivity both of the means of production and of the labour force.

Within this economic paradigm of production, terrestrial and aquatic ecosystems are sources of raw materials which, through the application of capital and labour, yield a marketable product. The primary productivity of the ecosystems, however – their natural capacity to elaborate vegetal matter through the photosynthetic process – is excluded from the overall conceptualization of their economic productivity. Lacking a market price, these natural processes appear as other "free" commodities, resistant to a process of valorization and to its incorporation in the regular practices of economic planning. The economic growth and the technological progress generated through the productive rationality inherent in this economic paradigm thus emerged as a process *contra natura*.

This productive process is characterized by the dominance of extraction, exploitation and the technological transformation of the natural resources of the environment over the ecological condition for their conservation and regeneration. The acceleration in the rhythm of capital rotation and the capitalization of the differential rent generated by the primary productivity of the ecosystems and the fertility of their soils in order to maximize profits or surplus in the short run, has produced growing pressure

on the environment. This has led to a progressive depletion of the abiotic resources of the planet and to the destruction of the ecosystemic structures and mechanisms that support the production and regeneration of biotic resources. Hence the productive process founded upon the technological productivity of capital has, in its expansive and accumulative tendencies, overexploited the natural and human resources of the planet. The destabilization of the natural ecosystems and the erosion of their fertile soils have been the results of such productive rationality.

The technostructures and specific technologies developed through this economic process have not been designed to function within a rational ecological management of natural resources. The dysfunctions and the productive irrationality of these technostructures are more evident when they are transferred and transplanted to ecosystems different from those of the temperate and industrialized regions where technological progress has evolved. When applied indiscriminately to tropical and underdeveloped regions, the social productive forces created through the technological harnessing of nature's laws become a *force destructive* of the material processes that are their source of wealth and development.

Nevertheless, the environmental problems of the underdeveloped countries cannot be solved merely by implementing appropriate technologies. People whose natural environments, cultural values and traditional practices have been destroyed in the process of "modernizing" their national society are forced into a series of destructive practices for their own survival because of the lack of land, of means of production and employment, arising from the land tenure structure, the economic and technological dependency and the sociopolitical and productive organization of these nations.

It is obvious that an environmental policy based upon mere remedial actions, or even on preventive instruments for diminishing the environmental and social cost of the capitalist rationality – that is, the evaluation of the environmental and social impact, and the taxation or the transfer of the costs of pollution and ecological destruction to the producers – could probably halt some undesirable projects, could change the social distribution of profits, or might even promote the choice of more adequate technological patterns. But such policies would be capable neither of reversing the mainstream of actions that are destructive of the environment nor of developing the productive potential of its resources to assure their renewability for a sustained process of development.

Scientific and technological progress has been strongly oriented towards the needs of the capitalist economic rationality. At the same time, it has generated innovative potential and has accumulated knowledge that can

be used to support an alternative project of civilization and to promote a strategy of development that is better adapted to different cultural and ecological conditions. It is possible to organize a process of production and application of knowledge for the development of the ecological, technological and social forces of production which is less subject to the logic of profits and surplus maximization, and more oriented towards the satisfaction of the basic needs and the quality of life of the people.

It is evident that the implementation of a productive rationality based upon the ecological potential of the environment is more urgent in those regions where the primary productivity of the ecosystems is higher, and where the functional structures and soil fertility are more vulnerable to the capitalist rationality and its technological modes of production (see Bifani, 1980; and Leff, 1985a). Nevertheless, its implementation will be appropriate and advantageous in any other region when the productive process is evaluated from the perspective of sustained development based upon the renewal of resources and when respect for the cultural values and life styles of the communities becomes an important goal in the overall strategy of development (McNeely and Pitt, 1985).

The construction of an ecotechnological rationality

An alternative paradigm of development, based upon ecological conditions for the productive use of the primary productivity of ecosystems, integrates the ecological processes that produce the natural use values with the technological processes that, in turn, transform them into socially necessary commodities. Thus the productive process is constituted by two complementary and interdependent levels of production:

(a) A level of ecological productivity which, based upon the natural conditions of the primary productivity of the ecosystems, is conditioned by the technological management of its structural functions and arrangements, and is subject to the social organization of the productive practices designed to benefit from its resources. These practices affect the actual output of natural resources, as well as the conditions for the conservation, regeneration and transformation of the ecosystems through the cultural valorization of their potential resources, the socioeconomic conditions for their exploitation, and the technological feasibility of their transformation.

(b) A level of technological productivity, characterized by the aggregate efficiency of the techniques, the means of production and the productive processes used to transform the natural resources offered by the ecological level into *socially necessary commodities*.

The productive process built upon the articulation of these two levels of productivity leads to the analysis of the technoeconomic conditions for the use and transformation of natural resources which maximizes the ecological potential of the environment and minimizes the depletion of resources.

The few principles exposed above point towards the necessity of constructing an alternative rationality of production. The conceptualization of the productive process as the articulation of a more complex, dynamic and flexible technostructure integrated into the overall ecological process of production and reproduction of natural and transformed resources offers a more holistic perspective for the integrated management of productive resources than the possibilities arising from current economic paradigms. The latter tend to confine the management of resources to separate sectors of the economy. Furthermore, social and ecological costs, as well as the distribution of social wealth produced by economic trends, appear as a "rational" exploitation of labour and capital.

The ecotechnological paradigm emerges from a new perspective of development, the natural productive potential of the earth, and the overall negentropic process arising from the ecosystemic laws of nature. This new centre of rationality radiates and generates new forces of development based on the geographical redistribution of the population, as well as on the organization and relocation of productive activities; these in turn will affect the quantity, quality and distribution of wealth through the decentralization of economic activities and the conservation of the natural and cultural diversity of the planet.

The productive process that would generate the ecotechnological paradigm thus depends on innovative social actions. It is a cultural and historical process. Ecological productivity, although based on natural productive potential and on the ecosystemic organization of the environment, is ultimately transformed by every culture and by the structure of every socioeconomic formation. Similarly, the technological process based upon the laws of nature is integrated into the organization of production, which is determined by a specific social rationality.

The ecological and technological structures, once transformed by the productive practices of social formations, acquire productive force and develop certain dynamics of their own. Nevertheless, the conditions of social organization affect the overall productivity of an economy somewhat independently of the social forces of production already incorporated into its ecological and technological means of production.

The possession of land and instruments of production, the national and international economic process, and the national and local sociopolitical structure, will determine the access of people to their resources, the periodicity and intensity of land use, and the actual investments in different regions.

The effective implementation of the paradigm of ecotechnological productivity demands an overall conception of social productivity with three articulated dimensions and interdependent levels of productivity.

1. A level of *cultural productivity*, where the cultural knowledge of the conditions of fertility and of the productive use of the ecosystems integrated into the productive practices of the communities becomes a working part of their overall social productivity. Their *ethnological style* of development defines certain ideological norms for the cultural perception of their resources, for the application of their technological means of production and for the consumption of their products. The social division of labour of the community, the social distribution of time for productive practices and for other purposes, and the organizational efficiency of their labour process, are some of the elements that contribute to this level of productivity. Traditional practices are assimilated into the ecological rationality of the productive forces, and, through the defence of their cultural autonomy, people contribute to the conservation and development of the productive potential of their environment.

The potential use of the resources of a community does not depend only on the technical properties of its means of production; it is subject to the social conditions of application to the cultural functions of the productive practices and to the life style of a social formation. The religious beliefs, the ethnic norms and the moral values of the people, as well as the forms of economic exploitation and of cultural domination which they have been exposed to, have determined their present productive organization as well as their capacity for assimilating new technological knowledge into traditional practices. The social access to, and collective participation of, the people in the management of their productive resources will thus not only affect the social distribution of wealth and the satisfaction of basic needs, but will also contribute to the social productivity of the community.

2. A level of *ecological productivity*, supported by the conservation of fertility and of the fundamental functional structures of the ecosystems which generate its productive potential, its conditions of stability, its overall state of fitness and the renewability of its resources. From these basic conditions, the primary productivity of the ecosystem can follow a *selective regeneration process*, subject to cultural practices and to the

application of modern ecological technology, in order to increase the output of socially necessary use values.

Thus the primary productivity considered here is not undifferentiated vegetal matter generated by the natural fertility of the soils, but the photosynthetic efficiency of certain ecological arrangements for the management of their resources. This primary potential is associated with several secondary biological and technological processes. These processes of secondary productivity depend on the levels of efficiency in transforming part of the vegetal resources through the different trophic chains of the fauna of the ecosystem. The biological productivity resulting from the integration of primary and secondary processes will depend on the varied possible associations of multiple uses of the vegetal resources and combined crops with different forms of livestock, aquaculture, fisheries, the culture of faunistic resources and wild animal management.

The spatial distribution of these biological resources, their material and energetic exchanges, the ecological recirculation of animal manures and the residues of other technological processes will establish new cycles of nutrients in the ecosystem and new dynamic balances of energy. The application of highly efficient biotechnological processes and the faster growth of species through genetic technologies and other scientific means will contribute to the overall level of ecological productivity.

3. A level of *technological productivity*, which basically depends on the transformative efficiency of an aggregate of mechanical, chemical, biochemical and thermodynamic processes. The interdependence of this technological level with the ecological and cultural dimensions described above demands a reorientation of scientific and technological efforts to construct an alternative economic and social rationality. This technological productivity cannot be dissociated from its positive and negative effects on ecological productivity nor from the effects of its assimilation into the labour process on the cultural productivity of the communities and on the quality of life. These systematic interrelations orient a prospective innovative process towards the constructing of a qualitatively different technostructure, and introduce new criteria for the choice and the social assessment of technology, leaving behind the simple controversy of capital– vs. labour-intensive techniques in economic development theory.

The ecotechnological paradigm also leads to more complex technological combinations than the one-dimensional alternatives proposed by the utopic return to traditional techniques, the idyllic use of small and soft techniques, the adjustment of economic factors through the creation of intermediate technologies, or the individual choice of adequate technologies for specific resources.

The complex matrix of the articulations of these three levels of social productivity opens the way to a broader understanding of the synchronic and diachronic articulation of ecological, technological and cultural processes as a basis for the integrated management of natural and social resources for sustained development. From a synchronic point of view, the articulation of these processes defines the actual resources available to a society through its ecological offer and renewability, its cultural perception and its technoeconomical valorization. But besides this systemic delimitation, there is a *systemic effect of creation of social resources and emergence of productive potentials*, resulting from the integrative force of these processes. The dialectic principle – the whole is more than its parts – is true for this purpose.

From a diachronic perspective, the articulation of ecological, technological and cultural processes integrates ecological evolution, technological innovation and social change into a historical process of transformation. The interdisciplinary paradigm arising from the systemic articulation of these processes is not intended, in this case, to work primarily as a systemic approach to the diagnosis of a complex reality nor as the articulation of sciences to constitute a new object of knowledge. Basically, it is a conceptual paradigm whose purpose is to guide social actions for the construction of an alternative productive rationality.[3] Once implemented, it could be contrasted with the prevailing rationality and tested in concrete cases.

From this systemic point of view, the integrated management of resources is supported by the articulation of their productive levels. These actually constitute a network or a *system of natural, technical and social resources*. Through the cultural and technological transformation of ecosystems for the production of socially necessary commodities, a *system of natural resources* (Morello, 1983) is formed.

The ecological technology developed to increase the primary productivity of ecosystems and to support a sustained selective regeneration of their resources depends on the aggregate of adequate techniques designed for the transformation of such a natural resource system. The concept of an *adequate technological* system emerges from the necessary interconnection of these techniques for the productive recirculation of by-products and residues, and from the alternative combinations and the possible technical choices for the integral transformation of these resources and for the multiple use and management of the ecosystems.

The technological system will thus be open to the combination of different sets of "economic factors". It will be conditioned not only by the availability of external financial sources for capital investments, or by

the availability of land and labour, but also by the ecological conditions for the renewal and productivity of natural resources and the incorporation of such principles into the productive practices of the communities. The construction of such a technological system will also be influenced by the degree of rigidity of the available technologies, in which past technical progress has crystallized, thus conditioning their capacity to adapt to this new productive rationality. Furthermore, its productive efficiency will depend on the cultural potential for assimilating new scientific principles and on technical capacities for re-creating some of their traditional practices and inserting them in their labour processes.

We can thus define an *appropriate technological system* as a techno-structure that, having internalized in its functions the primary productivity conditions of the ecosystem, takes on its concrete form and operates through a process of collective and subjective assimilation by the community. This embraces a process of assimilation of abilities, of internalization of knowledge, and of possession and control of the technological conditions by the people for the management of their productive resources.

Through the cultural values of a community, a technological system is integrated into its productive practices and operates as a productive force. Nevertheless, these cultural values are continually disrupted and modified by the demand for raw materials and by the exploitation of resources imposed by international economic conditions, as well as by national and regional strategies of development. Therefore, the articulation of the systems of natural and technological resources is defined and regulated by a *system of cultural values and by political and economic conditions*.

The orientation of a prospective planning process for the implementation of the ecotechnological paradigm of production is moulded by a system of values. This is not only directed towards the satisfaction of the basic needs of the people, but deals as well with the improvement of the quality of their lives. The three levels of social productivity (social, ecological and technological) will then emerge from the coming together of the dynamic processes involved in the articulation of the described systems of natural resources, of appropriate technologies, of cultural values and of economic conditions that define a system of socially necessary productive processes.

The implementation of the ecotechnological paradigm

The implementation of the ecotechnological paradigm of production calls for a series of institutional changes and the creation of new instruments for planning development processes in harmony with the environment.

These are beyond the scope of this paper. I will simply point out the need for new methods and indicators for the social assessment of this development strategy (Gligo, 1985), and for new orientations for the prospective planning of scientific and technological innovations. As for the evaluation process, it is necessary to create methods for analysing the social distribution of environmental costs and benefits, and to devise new instruments for the economic estimation of the social availability of resources and their productive potential under alternative regimes of use. These methods would in turn lead to the evaluation of alternative forms of integrated resource management. This process will necessarily be linked to a prospective programme of scientific research aimed at the discovery of new productive potentials of natural resources through the analysis of their properties, through the innovation of more efficient methods of photosynthetic transformation, through phytochemical and genetic improvements in the quality and rate of growth of usable resources, through biotechnological transformation of primary resources and through the development of new processes and products.

The social assessment of this ecotechnological process will necessarily differ from the economic calculations used in exploiting raw materials, which is based on the actual reserves and inventories of resources (Leff, 1985b). The institutional arrangements for the instrumentation of environmental policies will also differ from the sectorialized approach to the management of resources through separate government departments.

The implementation of the ecotechnological paradigm will require both these and other changes in the planning process, in its legal principles and in its research policies. But it cannot be made properly operational unless the communities themselves assimilate this new knowledge and improve their subsistence conditions through their own participation in the appropriation and management of their resources. This strategy of development will induce a process of integration at a national level through the respect for different cultural patterns of life, through the improvement of living standards generated by decentralized and sustained development, and through the political mobilization of the people to defend and develop the productive potential of their resources.

The ecological support of ecotechnological productivity

The project of constructing a productive rationality based upon the integrated use of the natural, technological and cultural resources of a nation, a region or a community finds its justification in the revalorization

of the social goals of the development process. These should focus on the quality of life of the people and their technological self-reliance, on the cultural autonomy of nations and ethnic groups, on the distribution of wealth and power through the decentralization of economic activities, and on the satisfaction of the physiological needs and the social demands of the people in a sustained development process. Yet, in order to attain these objectives, there must be enough proof of the real productive potential of the ecotechnological paradigm. This will not remove obstacles arising from economic interests and the power structures that sustain the capitalist rationality, but it will invalidate many of the ideological defences that legitimate current productive practices, and will give our "utopic" paradigm stronger scientific support.

Implementation of the ecotechnological paradigm is most urgent and necessary in the intertropical region of the planet, not only because its ecosystems have the highest primary productivity potential, but because these regions are suffering an intensified process of irreversible degradation of their ecosystems and of erosion of their soils due to the implantation of inappropriate technological models of production.

In the tropical rain forests, the basic rate of formation of phytomass can reach levels of 10% annually (see Rodin et al., 1974). This "natural" productivity may seem small in comparison with yields of 100% for some cash crops. Nevertheless, in the first case, we are dealing with an ecological process of sustained formation, while the second is an artificial process, achieved through the destabilization of the ecosystem and the injection of high energy costs from non-renewable resources, which can only operate for short periods of time and which leads to rapidly decreasing yields and rising costs of production (see Rosenzweig, 1971). This affects the future fertility of the soil and can seriously disrupt the ecosystem's mechanisms for renewing its natural resources.

This ecodestructive process has been the predominant tendency since the colonization of the tropical regions, which altered the traditional uses of land and its resources. The capitalist valorization of certain primary products and raw materials determined the expansion of the agricultural use of land and the implantation of crops that would yield the maximum benefits in the international markets (see Nelson, 1977). This process has destroyed the natural diversity of biological communities on which both the stability and the primary productivity of the ecosystems depend. International financing for the export of Third World resources has reinforced this exploitation pattern, inducing increasing rhythms of rotation of capital investments for the payment of foreign debts, and

resulting in a growing pressure on the ecosystemic structures, on their carrying capacity, and on their resilience.[4]

This process has degraded the productive capacity of the ecosystems and depleted the reserves of many non-renewable resources in the underdeveloped nations, destroying their ecological potential to generate independent and sustained development.

Whether the ecotechnological paradigm is operational or not depends on the conservation of the basic functional structures of the ecosystems and on the fertility of their soils if they are to maintain a maximum sustainable output of usable biomass. The paradigm can be applied to the multiple use of a complex natural ecosystem as well as to the integral management of transformed environments and cropping fields. In any case, its viability is based on choosing ecological arrangements that, while conserving the regulating mechanisms for regeneration of a system of natural resources, will yield the maximum output of socially necessary use values (Leff, 1985a). In the long run, this productive system will depend on the stability of the ecosystems that support them (Holling, 1973).

The uncertainty about the sustainability of a process of integrated management of resources arises from the danger that these thresholds of stability may be crossed as a result of natural catastrophes or because of forms and rhythms of exploitation that exceed the recharging capacity of the ecosystem, or its resilience. Nevertheless, many ecosystems are multistable, so their normal process of evolution will reach successive breaking-points of transformation. This will modify the whole ecosystem and its natural resources. Hence an analysis of the levels of stability and the possible transformations of an ecosystem is essential for the prospective planning of an appropriate technological system (see Gallopin, 1983).

On the elaboration of an interdisciplinary indicator of productivity

Up to this point, I have tried to justify the construction of a new productive rationality based on the heuristic concept of ecotechnological productivity. This suggests the integration of specific concepts of productivity from different fields of knowledge that deal with the primary and secondary productivity of biological resources, with the contributions of capital and labour to the measurement of agricultural yields, and finally with the technological productivity of productive processes. Yet, making such a concept of ecotechnological productivity operational requires a certain measurement of its level of productivity, if not in order to compare

it with the concept of economic productivity, then at least to be able to contrast different experiences and possible ecotechnological models. Other qualitative criteria are necessary to evaluate in a more concrete way the sense and effects of this paradigm (e.g., environmental quality, quality of life, sustained development, and the social cost and benefits of alternative ecotechnological strategies). For this purpose, it is necessary to transform the heuristic abstract concept of ecotechnological productivity into *operational indicators* for the implementation of this strategy of development. I do not intend to do this here, but will only advance some general criteria for the construction of these practical instruments.

The ecological level of productivity differs from the concept of primary and secondary productivity used in ecology. From the general perspective of the ecotechnological paradigm, ecological productivity includes both these levels, as well as biotechnological processes and the overall ecological technology used to transform the natural resources system. The objective of an indicator of ecological productivity is to estimate the actual productivity of such a system as well as its ecological potential to generate use values and consumable commodities. This goal is beyond the measurement of the overall biotic productivity of the ecosystem. In this sense, the rate of production of use values differs from the basic rate of biomass formation of the ecosystem. Ecologic productivity can be referred to in terms of time and space (i.e., the total annual output of commodities produced on a certain surface). For the purposes of national accounting, its market value can be seen in terms of the cost of capital and labour invested, but for the simulation of different technological arrangements, labour time and total inputs of energy will yield more workable data.[5]

The economic concept of technological productivity is often linked to a theory of growth and distribution. It is thus associated with an accumulative process. But the ecotechnological productivity for sustained development cannot be measured as a process of annual increases of economic value, or even in terms of material and energetic output. The ecotechnological paradigm defines its basic rate of growth both by the process of regeneration of its resources and as a renewable rate of formation in alternative patterns of integrated use for a sustained production of socially necessary commodities.

The technological productivity within this paradigm will be measured purely in terms of thermodynamic efficiency and will be controlled by ecological and cultural norms. Its contribution to social forces of production is associated with, but does not depend only on, its economic value. Technology is not a free commodity. It involves a certain cost of production

which is transferred to all the means of production. If technological progress focuses on constructing a more stable and multifunctional technostructure instead of on constantly replacing equipment generated by the creative destructive process of capitalist dynamics, then the major costs of production of our technological system will be those related to research and development activities. Nevertheless, the relation of these costs to technological productivity is not a linear nor a predictable function.

Similarly, the cultural productivity arising from the innovative reconstruction and adaptation of traditional practices, and from the productive organization of the community, cannot be accounted for in terms of capital or labour investments. Neither can the role of workers in the labour process, nor the "productive spirit" of the people. The social development of productive forces stemming from scientific creativity, technological innovation and social motivation cannot be measured as annual productivity rates; its effects can only be evaluated in terms of a sustained process of development.

The above arguments show the incommensurability of the ecotechnological paradigm with the economistic rationality. Yet different models and patterns of the use and transformation of resources can be compared by analysing total inputs and the flow of energy needed to generate a certain quantity and quality of use values. Thus the solar energy and the energy cycles of the ecosystems, the energetic efficiency of the photosynthetic process and of the trophic chains, the energy expended in the labour process and the energy used in technological processes, will find a common denominator. Nevertheless, the quality of life depends more on a sense of participation in, and the fulfilment derived from, the objectives of a social project than on the quantity of energy used in the productive process; the quality of the environment depends more on the conservation of the basic productive structures for the renewal of its resources, on the ecotechnological capacity to recycle residues, and on the overall degradation of energy, than on the quantity of energy that flows through the overall productive process.

The ecotechnological rationality as a negentropic process

The above criteria show the complex conceptual problems that we have to face if we are to construct indicators for evaluating the articulation of ecological, cultural and technological processes that could serve as

guidelines for selecting alternative projects within the ecotechnological paradigm and assessing their suitability as strategies of sustained development. From a material and energetic perspective, the productive processes that support the ecotechnological rationality and its physical viability are oriented towards constructing a *social negentropic process* to oppose and counterbalance the growing entropic tendencies of the capitalist rationality.

The increasing use of energy has been assumed to be a law of evolution of human society, together with economic growth (see Adams, 1975). Yet its effects on the depletion of resources and the entropic degradation of this energy, together with the projected effects on the ecological equilibrium of the planet based on the extrapolation of this productive rationality, have raised the ecological alarm and have led to calls for the suspension of economic growth.[6]

In contrast to the contradictions between the theoretical basis of the capitalist rationality and its practical prescriptions, the ecotechnological rationality offers new options for sustained development. In this sense, it can be contrasted with the capitalist rationality in terms of its overall entropic tendencies. The negentropic orientation of productive processes within the ecotechnological rationality goes beyond controlling and reducing the total amount of energy used by present technologies. Moreover, it aims to reverse the entropic tendencies of degradation of an environmental potential of development (the increasing depletion of natural resources, the destructuring of productive ecosystems, the loss of traditional appropriate practices and the degradation of potential energy), by increasing the contribution that both the biological and natural processes of formation of natural resources and inextinguishable sources of energy make to the overall productive process of social goods.

In a broader sense, the negentropic tendencies of social development, beyond conserving certain structures and ecosystemic organizations for sustained development, point towards a historical heterogenetic process of increasing complexity in productive practices arising from stronger social cohesion, national autonomy and cultural diversity. This project would oppose the historical trends towards the international division of labour, the simplification of productive abilities, the unity of empirical knowledge and the technological uniformity of landscape and cultures, all of which are needed for the rise in economic productivity and for the international expansion of the capitalist rationality.

Final remarks

In this paper I have attempted to develop a conceptual basis for the integrated management of resources oriented towards the construction of a *paradigm of ecotechnological productivity*. This process should be viewed as a *constructive abstraction*, in the sense given by Mannheim,

> to assist in reconstructing structural forces which are present in reality although not always obvious. . . Constructive abstraction is a prerequisite for empirical investigation, which, if it fulfils the anticipations implicit in the concepts or, more simply, if it supplies evidence for the correctness of the construct, gives to the latter the dignity of a reconstruction (Mannheim, 1972, p. 182).

This ecotechnological paradigm thus appears as a utopic project, but not because of a lack of a material basis at the interlinking levels of natural, ecological, technological and cultural productivity for generating a sustained development process. Its main obstacles are institutional rigidities, as well as the political and economic interests of the capitalist rationality. The replacement of this rationality by an ecotechnological paradigm is not a short-term goal. Nevertheless, the tension created by the two opposing paradigms should stimulate the emergence of more environmentally sound practices. These in turn will promote a conservation strategy for sustained development. This would be more effective than present remedial actions which are intended to lessen the environmental and social costs of the productive rationality that commands the economic exploitation of our resources, as well as our thoughts and actions.

Enrique Leff (born 1946) is Researcher at the Instituto de Investigaciones Sociales, Universidad Nacional Autonoma de Mexico. He is engaged in a research project on the "Transformation of knowledge from the environmental perspective of development". In addition to the books and articles mentioned, he has published: "Sobre la articulación de las sciencias en la relación naturaleza-sociedad", in: Leff (coordinador) *Biosociologia y Articulación de las Sciencias* (1981) and "Ethnobotanics and anthropology as tools for a cultural conservation strategy", in: J. A. McNeely and D. Pitt (eds), *Culture and Conservation* (1985). *Author's address*: Instituto de Investigaciones sociales, UNAM, Torre dos de humanidades, 9° Piso, Mexico, D. F., C. P. 04510, Republica Mexicana.

Notes

1. A good example is the contrast between the two opposing world models of Meadows *et al.*, *The Limits to Growth* (1972) and Herrera *et al.*, *Catastophe or New Society? A Latin-American World Model* (1976).

2. I first hinted at this concept in my articles "Hacia un proyecto de ecodesarrollo" (1975) and "Biosociologia y ecodesarrollo" (1976). See also Leff (1985a).

3. I develop this point in "Ambiente y articulación de ciencias" (1986).

4. The resilience of an ecosystem is its capacity, based on its internal mechanisms of regulation, to absorb external impacts without modifying its basic conditions of stability. Resilience is associated with historical transformations due to natural phenomena or to cultural practices. It will then function as a degree of resistence with a capacity to adapt to new technological patterns and to the rate of exploitation and forms of management of the ecosystem.

5. Rappaport (1968, 1971) is one of the pioneer studies in the use of this methodology.

6. For a critical overview of these ideas, see "The no growth society", *Daedalus*, Fall, 1973.

References

Adams, R. N.
1975 *Energy and Structure: A Theory of Social Power*. Austin, Texas University Press.

Barnett, H. J.; Morse, C.
1963 *Scarcity and Growth: The Economics of Resources Availability*. Baltimore, Johns Hopkins Press.

Beanlands, G. E.; Duinker, P. N.
1981 *The Ecological Basis for Environmental Impact Assessment*. Morges, IUCN/CEP.

Bifani, P.
1980 *Desarrollo y Medio Ambiente*. Madrid, CIFCA (Cuardenos del Cifca, 24).

CEPAL/PNUMA
1984 "Incorporación de la dimensión ambiental en la planificación", *Revista Interamericana de Planificación* 18 (69): 9–51.

Gallopin, G. C.
1983 *Tecnología y Sistemas Ecológicos*. Madrid, CIFCA (Opiniones, Tecnología y Medio Ambiente, 1).

Gligo, N.
1985 "Consideraciones en torno a evaluaciones e indicadores para la gestión ambiental" and "Hacia la elavoración de inventarios y cuentas del patrimonio natural y cultural". Papers presented at the Primer Seminario Latinoamericano de Sistémas Ambientales para la Planificación, Mexico, UNAM.

Gutman, J. P.
1986 "Economía y ambiente", in: E. Leff (ed.), *Los Problemas del Conocimiento y la Perspectiva Ambiental del Desarrollo*. Mexico, UNAM/Siglo XXI.

Herrera, A. *et al.*
1976 *Catastrophe or New Society? A Latin-American World Model*. Ottawa, International Development Research Centre.

Holling, C. S.
1973 "Resilience and stability of ecological systems", *Annual Review of Ecological Systems* 4: 1–23.

Leff, E.
1975 "Hacia un proyecto de ecodesarrollo", *Comercio Exterior* 25 (1): 84–92.
1976 "Biosociología y ecodesarrollo", in: E. Leff (ed.), *Primer Simposio sobre Ecodesarrollo*. Mexico, Asociación Mexicana de Epistemología.
1985a *Ecología y Capital: Hacia una Perspectiva Ambiental del Desarrollo*. Mexico, UNAM/Siglo XXI.
1985b "El cálculo económico en la planificación ambiental del desarrollo", *Revista Interamericana de Planificación* 19 (73): 56–64.
1986 "Ambiente y articualción de ciencias", in: Leff (ed.) (1986).

Leff, E. (ed.)
1986 *Los Problemas del Conocimiento y la Perspectiva Ambiental del Desarrollo*. Mexico, UNAM/Siglo XXI.

McNeely, J. A.; Pitt, D. (eds.)
1985 *Culture and Conservation*. Worcester, Billing.

Mannheim, K.
1972 *Ideology and Utopia*. London, Routledge and Kegan Paul. (1st edn 1936).

Meadows, D. H. *et al.*
1972 *The Limits to Growth*. New York, Universe Books.

Morello, J.
1983 *Manejo Integrado de Recursos Naturales*. Madrid, CIFCA (Opiniones, Recursos Naturales, 5).

Nelson, M.
1977 *El Approvechamiento de las Tierras Tropicales en América Latina*. Mexico, Siglo XXI.

Rappaport, R. A.
1968 *Pigs for the Ancestors*. New Haven, CT, Yale University Press.
1971 "The flow of energy in an agricultural society", *Scientific American* 224 (3): 116–132.

Rodin, L. E.; Bazilevich, N. I.; Rozov, N. N.
1974 "Primary productivity of the main world ecosystems". Paper presented at the First International Congress of Ecology, The Hague.

Rosenzweig, M. L.
1971 "Paradox of enrichment: destabilisation of exploitation of ecosystems in ecological time", *Science* 171: 385–397.

Sachs, I.
1971 "Approaches to a political economy of environment", *Social Science Information* 10 (5): 41–53.
1980 *Stratégies de l'écodéveloppement*. Paris, Les Editions Ouvrières.
1982 *Ecodesarrollo, desarrollo sin destrucción*. Mexico, El Colegio de México.