Technological Change in Agriculture: A Marxist Critique

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The severe crisis facing agriculture today, and the agro-food system in general, reveals itself by a growing instability of world markets, increasing competition and protectionism, serious fiscal stress at EU or country level, and increasing surpluses of some agricultural or food products, while millions of people, especially in the underdeveloped countries, are under poverty and directly facing famine. It is also expressed by environmental degradation or destruction, a massive dispossession and expulsion of rural populations from the agricultural sector and, finally, by significant social unrest and protest among farmers in many countries.

According to the widely-accepted approach (Goodman and Redclift 1989; Friedland et al. 1991; Friedmann 1993), which I have elsewhere characterized as structuralist-Marxist (Liodakis 1995), the main causes of this crisis are: a) the collapse of the post-war mode of regulation or, according to others, of the ‘agro-food regime,’ b) the development in US and international dissemination of a model of technological innovation and intervention in agriculture (intensive, industrialized and energy-consuming agriculture), c) the representation and legitimation crisis facing the capitalist state and international organizations in relation to the agro-food policy followed, and d) the failure to anticipate or contain environmental problems (Goodman and Redclift 1989). This interpretation covers several, but not all aspects of reality. Contrary to this view, I would argue that the crisis facing the agricultural and food sector today stems from an extension of the structural over-accumulation crisis of world capitalism, which of course varies in the agricultural sector, in terms of forms and intensity, according to natural qualities and social and technological characteristics at a regional and national level.

The serious consequences of the crisis have also led to a search for solutions to the associated problems. From the dominant policy point of view, more
intense technological modernization is usually sought, aiming at improved competitiveness of agricultural production. Technology is considered to be exogenous and socially neutral, and is utilized to solve problems facing agriculture, while in reality the dominant technological model itself bears a considerable part of the responsibility for bringing about the problems we face today. This policy is based on the dominant deterministic conception of technology, which should be rejected because it considers technology as socially neutral and as an independent, exogenous variable, while focusing almost exclusively on its impact on production and society (e.g., Samaras et al. 1994). This positivist conception considers technological change as a linear evolution, attributes an absolute role to the (presumably neutral) technological modernization, and ideologically legitimizes the technological pattern of western capitalism, whether technology in general or agricultural technology in particular (MacKenzie and Wajcman 1985; Busch et al. 1989; Shiva 1991). Moreover, the positivist character of this conception of technological change obscures the real impact of any particular technology, while excluding the possibility of conceiving or seriously examining any alternative model. In reality of course, the development of any technology implies benefits for some people and costs for others, and in this sense it cannot be considered as socially neutral (Winner 1985; Liodakis 1987; Busch et al. 1989; Harvey 1993). By its very nature it contains a social and political element, obfuscated by technological determinism or variations of it, which treats the development of technology simply as a technical issue or as a relationship between inputs and output.

From an alternative, and often ecological perspective, increasing interest is being shown in sustainable agriculture, such as ecological or biological agriculture, and alternative agricultural technology. The extensive literature which has been developed around 'sustainable development' or 'sustainable agriculture,' shows considerable vagueness towards the concept of 'sustainability' itself, as it does not specify exactly what is to be sustained and for whom, and provides insufficient theoretical foundation for the corresponding developmental perspective (Pretty 1995). Perhaps the most significant version of 'sustainable agriculture' rejects the dominant model of development and technological modernization of agriculture, and emphasizes the utilization of biological cycles, the preservation of ecosystems, the use of internal (local) inputs, the reduction of agricultural dependence on external inputs (provided through the market), and the utilization of indigenous technology and local agricultural know-how. This approach parallels the more general trend of deregulation and stresses the importance of local development, which is recently in vogue. The narrow focus (on local, biological and technical elements) of this approach, however, restricts its usefulness as an alternative proposal. The consequence of this restriction is that it obscures the significance of the social relations of production, the social determination of technology and the transition process to a different organizational model, while ignoring the potentially beneficial impact of social interdependence at a global level.
The purpose of this paper is, in the first place, to review the main contemporary forms of agricultural technology and evaluate, in general terms, the impact of the dominant model of agricultural technology. This will be done in section two. Mainly for practical reasons, I shall focus on the agricultural sector and not so much on the broader context of the 'agro-food system' (Friedland et al. 1991; Raynolds et al. 1993; Goodman and Watts 1994; Liodakis 1995). On this basis, the major theoretical models of agricultural technological change will be reconsidered, in section three, and an alternative, dialectical approach will be proposed regarding the determination and social character of technology. Subsequently, an attempt will be made, in section four, to evaluate critically alternative strategies for overcoming the current crisis and facing some of the major problems of the agro-food system at a national and world level. I will try to identify the main points of an alternative, Marxist approach and corresponding strategy of economic and technological transformation. These concern understanding the current crisis and the nature, character and dialectical determination of technology. Regarding the inevitable agricultural restructuring, my main argument challenges the 're-localization thesis' and the idea that client-driven research, aiming to develop an appropriate and ecologically compatible agricultural technology, could be effectively brought about by the market mechanism.

The main trends of agricultural technology and the socio-economic and environmental impact of technological modernization

Before I examine the main trends and particular forms of agricultural technology, it will be useful to clarify the concepts of technology and technological innovation themselves. Leaving apart the distinction between technique and technology (MacKenzie and Wajcman 1985; Liodakis 1987; Samaras et al. 1994), by referring to technology in general or to agricultural technology in particular, I mean the totality of the specifically and intentionally shaped means and objects of labour, organizational forms and methods of production, human knowledge and planned administration of means and methods, which are utilized in the production of certain products or intended effects. By the term technological change or innovation, I correspondingly understand any change (improvement) in the above elements composing technology, including any change (improvement) in the means, objects, methods and the organization of production-transportation-distribution and consumption, the invention and production of new products, and the development of new markets. It becomes clear, from the above definition of technology, that it may have an embodied character, as in the case of certain products or means of production, or a disembodied character (e.g., methods, organization, know-how). More specifically, the production of commodities deriving from scientific developments and changes in production technology, but also from a corresponding change in the class structure and social division of labour, simultaneously implies a transformation of both the forces
and the relations of production themselves. As Marx has pointed out, "technology discloses man's mode of dealing with Nature, the process of production whereby he sustains his life, and thereby also lays bare the mode of formation of his social relations, and of the mental conceptions that flow from them" (1967, I, p. 352).

The particular forms of agricultural technology have historically undergone rapid change during this century and particularly during the post-war period. They also vary geographically according to the particular characteristics and the types of agricultural production. These technological changes include mechanization, the development of irrigation systems, new methods of cultivation or systematic stock breeding, the use of chemical fertilizers, herbicides or insecticides and improved varieties of seed or animal species, etc. In the past, the combination of some particular forms of technology with certain policies put forward by advanced countries or international organizations has been formulated and disseminated worldwide as specific models of agricultural technological development. Here, apart from the American model of intensive agriculture, reference should also be made to the model of the so-called Green Revolution, developed by the advanced western countries around the early 1960s, to be utilized in underdeveloped countries so that, by resolving intense food shortages, social explosions might be avoided. The Green Revolution technology combines the use of seed of improved high-yielding crop varieties (mainly cereals) with intensive mechanization, fertilizer and irrigation. A result of this rapid technological progress on a world level, and of the Green Revolution in particular, was the immense improvement of agricultural labour productivity and production growth. This apparent progress, however, did not come about without serious costs, as noted in the introduction.

Modern microelectronic and information technologies and biotechnology have, during recent decades, acquired great importance in the agro-food sector as well. Their significance will be even greater in the future, and their impact very deep. Information technology and use of computers in all activities associated with production, transportation, processing and marketing of agricultural products are gradually spreading, acquiring an important role in the transformation of agricultural processes and relations.

Biotechnology acquires even greater significance. More specifically molecular biology and genetic engineering have already led to revolutionary changes, opening great horizons for agriculture and the increase of labour productivity (Busch et al. 1989; Samaras et al. 1994; Parker and Zilberman 1995). So far applications of biotechnology mainly concern agricultural inputs and food-processing industries, although the development of new seed varieties and livestock strains has brought about very important changes in the primary agricultural sector as well (Kloppenburg 1988; Shiva 1991). Biotechnology may affect agriculture in two main ways. By expanding production, it may exacerbate the existing problem of agricultural surpluses, while on the other hand it may reduce this problem by offering alternative uses of agricultural staples or
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development of new products. Two-thirds of biotechnological research is associated with pest-control products, and only one third with the introduction of new products or the improvement of product quality (Parker and Zilberman 1995). This irrationality and overall bias in relevant research and biotechnological development—stemming from the fact that they are privately controlled by multinational corporations—lead in directions not so much useful and needed, as amenable to commodification and capable of generating profit (Shiva 1991).

In general, biotechnology creates immense possibilities, but also implies serious risks, mainly for the environment, health, biodiversity and the development prospects of less-developed countries (Kenney 1983; Kenney and Buttel 1985; Busch et al. 1989; Shiva 1991), which are usually hushed up or minimized. Because biotechnology research needs to be selectively promoted in areas creating benefits and abating risks, because relevant research may require enormous investments, and because the results or products of biotechnology research may acquire the character of a public good, making it difficult for private agencies to exclusively exploit and appropriate the relevant benefits, the need for the state to undertake a substantial role in this area is obvious (Lowe et al. 1990; Parker and Zilberman 1995).

Multinational corporations do not only control research and the products of new technology, but also the major sectors of traditional technology (machinery, fertilizers, etc.) and food processing, thus extending their control downstream as far as the primary sector of agricultural production. Multinationals are, thus, evolving into major agents of internationalization and accumulation within the broad context of the agro-food system. At the same time, they constitute decisive agents determining the rate, character and orientation of agricultural technological development. This role of corporations, reinforced by the growth of university-industrial complexes (Levidow 1993; Parker and Zilberman 1995), and the dominance of the market mechanism contribute to a systematically biased and one-sided development of research and technology.

Contemporary technological developments in the agricultural sector and the parallel industries of agricultural inputs and food processing have also led, according to some authors (Goodman et al. 1987), to two very important trends. The first trend (‘substitutionism’) concerns the tendency to substitute new industrial materials or synthetic elements for previously used agricultural raw materials. The second trend (‘appropriationism’) refers to a transformation of discrete activities into sectors of the agro-industrial complex of accumulation and to their re-incorporation in agriculture in the form of produced industrial inputs. In this way, the significance of nature and associated uncertainty in agricultural production processes are presumably restricted, while the dependence of agricultural production on industry is increased.

Despite the accumulating elements of crisis pointed out in the introduction, for which technology itself is partly responsible, many authors and international agencies still continue to propound the positive aspects of technology and to firmly support the view that the dominant model of economic and technological
development in the agricultural sector is the only realistic and scientifically based one (Hayami and Ruttan 1985; Samaras et al. 1994; Pretty 1995).

Having reviewed the main forms and trends in agricultural technology, I now focus on the character of technology and some negative socio-economic and environmental impacts of the dominant model of agricultural technological development or of the Green Revolution more specifically. The impact of technological changes on agricultural activity, the massive exodus and expulsion of millions of farmers from their home background is, in the first place, very familiar. Technological advance has also substantially contributed to the concentration of agricultural production and capital, while leading a great number of mainly small and medium family farms to marginalization and economic destruction. The important technological changes, from the Green Revolution to the more recent biotechnological revolution, have further led to significant shifts in the use of land, particularly in some countries where specialization and monoculture have been more pronounced, and in the international division of labour, as well as to partial transformation of agrarian productive relations, to considerable instability in world markets, and to differentiation in the specialization process (Buttel et al. 1985; Goodman and Redclift 1989). Extensive use of agro-chemicals and pesticides has not only increased farmers’ dependence on the market, but also led to a considerable de-skilling of agricultural labour (Vandeman 1995).

As is well-known, technological developments in the agricultural sector, particularly during recent decades, have also led to some destruction or serious degradation of the natural environment (Redclift 1984; Goodman and Redclift 1989). Environmental impact includes soil erosion, the contamination of water by pesticides, nitrates and livestock wastes, with damaging effects on the flora and fauna, ecosystems and human beings, as well as the contamination of food and fodder by residues of pesticides and antibiotics. It includes atmospheric pollution by ammonia, nitrous oxide, methane and the products of burning, with all familiar consequences, the overuse and depletion of natural and water resources, and dramatic decrease of biodiversity (Pretty 1995).

These negative effects have derived to a great extent from the application of the resource- and energy-intensive American model of agricultural technology, a cornerstone of which is the grain-feed-livestock complex and the corresponding formation of food patterns. Negative effects have also followed from the application of the Green Revolution, initially in some Third-World countries, but to some extent also in the developed countries. Despite the fact that state agencies, international organizations and the involved multinationals continue promoting the positive effects of the Green Revolution in most glowing terms, the actual experience after twenty to thirty years of application is not merely contradictory, but in some countries exceptionally bad (Cleaver 1972; Shiva 1991).

Although the Green Revolution was designed as a techno-political strategy for peace, in reality it has left certain regions, such as the Punjab, ravaged by violence and ecological scarcity, with diseased soil, pest-infested crops, water-
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logged wastelands, and debt-ridden and discontented farmers (Shiva 1991). The apparent productivity increases are largely a misleading myth, because the famous high yielding seeds have to be combined with large doses of complementary inputs (fertilizers, pharmaceuticals, irrigation). Also the measurement of benefits by narrow private criteria does not take into account the invisible externalization of a great part of the cost stemming from the utilization of technological processes which are destructive or intensive in the use of natural resources (Shiva 1991). The transformation of the seed, from a common resource controlled by the farmer, into a commodity ('input'), and the prevalence of monocultures has also resulted in extensive reduction of genetic diversity (Shiva 1991). As historical evidence shows, the use of inappropriate technology does not offer a solution to the problem of underdevelopment, but may in fact aggravate it in so far as poverty and underdevelopment are very often the outcome of a destruction of ecosystems or of resources necessary for survival.

It has already become obvious that no single technology can really be considered socially neutral, and in general, unequivocally progressive. A certain technology may serve the priorities and interests of those who produce and control it, but may have destructive consequences for other social classes or groups and for the environment. The conventional identification, therefore, of development with (presumably neutral) technological modernization, and of the latter essentially with the adoption of the dominant (western) model of agricultural technology, is at least misleading (Levins 1986; Shiva 1991).

An additional risk, created by the capitalist exploitation of biotechnology is the tendency to establish private property rights and monopolistic control over new varieties or forms of life. A specific case in point concerns the incorporation in the last GATT Agreement (1994) of the particular agreement under the title TRIPS (Trade Related Intellectual Property Rights). The problem here is that the establishment and exploitation of such rights by multinationals and countries like the US implies, on the one hand, the devaluation of productive efforts and centuries of experience of farmers mainly in today’s Third World. On the other hand it implies the monopolistic usurping of values, the production of which is largely based on exactly this accumulated genetic information. To the extent that such an agreement (TRIPS) will be applied in practice, it will imply for most developing countries a destructive entanglement in the traps of indebtedness and underdevelopment.

A reconsideration of the theory of technological development: a dialectical proposal

Examining briefly the process of technological development and the latest theoretical models, I shall not attempt to cover the diffusion of technological innovations at farm level (Samaras et al. 1994). I shall rather focus on technological development as a macro-economic process. In Marx’s analysis of the
development dynamic of capitalism, permanent pressure for mechanization and introduction of technological innovations derives from the nature of capitalist competition itself, and implies the appropriation of surplus profits from the innovating producer, as well as the greater control and exploitation of the worker (Marx 1967, I, ch. 15.1).

Concerning the development and diffusion of agricultural technology more specifically, apart from the so-called 'technology treadmill model,' which refers to the tendency of farmers to adjust to the competitive pressure of technological modernization (Busch et al. 1979), the model of 'induced innovation' (Hayami and Ruttan 1985), has exerted considerable influence within the neoclassical approach. Technological innovations and the pattern of development of the agricultural sector are induced, according to this model, by the signals emitted by the price mechanism, and are endogenously determined by the relative scarcity of the three factors of production. It should be noted here, however, that essential problems about the particular space of technology development, the necessity for its transfer to non-technology-producing countries, and the appropriateness of the particular technology for these latter countries, are sidestepped in this model. It should moreover be noted that the endogenous determination of technology in this model only relates to the market mechanism, and is reduced to a simply technical issue, while in respect to society and the overall dialectic between the forces and relations of production, technology is still considered as essentially an exogenous factor.

A critical approach to the 'theory of regulation' and 'flexible specialization,' can also shed some light on certain aspects of agrarian technological and social development. However, these models too show some serious weaknesses, associated mainly with the relevance of 'Fordism' as a concept, a misrepresentation of the causes of the current capitalist crisis, which over-emphasizes structuralist characteristics at the expense of more essential aspects of the relations of production. With respect to technology, these approaches usually constitute variations of technological determinism, while their significance for countries of low or medium levels of development and particularly for the primary sector of agricultural production, is limited (Liodakis 1993, 1995; Goodman and Watts 1994). Being intimately related to the above-mentioned structuralist-Marxist approach, this approach focuses on the form of technology and economic relations, at the expense of a more profound value-theoretical approach, which grasps more essentially the content of these relations.

In an attempt to theorize technological development from an alternative, Marxist standpoint, the context of this development is of crucial importance. More specifically, the investigation of the processes and prospects of technological change in agriculture needs to be carried out within the context of the 'agrarian question.' A contemporary, adequate conception of the agrarian question should cover not only the transformation of the social relations of production and the development of capital in agriculture, but also a) the interrelation of agriculture with the industrial or other economic sectors, and b) state intervention
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in agriculture and its contribution to the integration of these sectors and creation of the preconditions for accumulation both in agriculture and in the economy as a whole (Byres 1995). This conception should also include the contemporary search for a different role for agriculture and for an alternative model of development, beyond and independent of the currently prevailing capitalist model of development.

It may be useful here to point out some of the characteristics of the agricultural sector, with implications for the forms, patterns and potential rates of technological development. These characteristics include the following:

- the natural-biological element – which in the first place constitutes a basic determinant of agricultural production and creates a variety of conditions and a vast range of circumstances – offers some possibilities and advantages, but also raises some uncertainties and limitations;
- the diversity of agricultural production and the impossibility of automation and complete substitution of human labour;
- the fact that it is impossible to insulate agricultural production, as it is to some extent possible in the case of industrial or in laboratory production, from its ecological impact and consequences;
- The fact that some changes in agricultural technology are in the long term or permanently incorporated in the land (land improvements) or in permanent plantations, whose property rights are controlled by certain farmers or landowners;
- the theoretically debatable but usually empirically verified tendency for a formation of a lower organic composition of capital in the agricultural sector vis-à-vis the industrial sector (Marx 1967, III, p. 760). This obviously restricts the profit margins and the return on capital in the agricultural sector, and as a consequence probably also the potential for development of technology and productive forces in this sector. Private ownership of land also plays a very important role here (Marx 1975, II, p. 96, III, p. 301; Marx 1967, III, pp. 770–72).

Now all these, which concern the material conditions and the peculiarities of the agricultural sector, constitute more or less well-trodden ground. It is also well known that these conditions contribute to the prevalence of some organizational forms in agriculture, such as the private family or capitalist farm, and to the persistence, particularly in some countries or regions, of a great number of small family farms, which usually restricts the potential for development and diffusion of technological innovations in the agricultural sector. Hence, the historical necessity for social or state intervention aiming at the restructuring of land-holding relations and the promotion of technological development.

What needs to be demonstrated more specifically is how the process of technological change is associated with these material conditions and characteristics of the agricultural sector. In the Marxist tradition there is a long-standing Soviet orthodoxy associated more generally with the so-called Marxist-Leninist view and the corresponding strategy of socialist transformation. This approach,
which could be characterized as ‘modernist Marxism’ (Saad-Filho 1996), attributes an absolute primacy to productive forces, vis-à-vis the relations of production, and strategically expects that the growth of the productive forces will automatically lead to the adjustment and qualitative change in the relations of production. Thus the forces of production, and technology, which is a constituent element of these forces, acquire a more or less autonomous and deterministic role. According to this positivistic and rather optimistic perception, organizational and technological modernization is a crucial precondition for the rapid and cumulative development of the productive forces. In practice, however, both in the Soviet Union and in other countries where a course of socialist transition has been followed, this approach and the associated development strategy have led to increasing social tensions, considerable degradation of the natural environment and ultimately to the collapse of the transitional process (Kiely 1995; Saad-Filho 1996).

On the other hand, there is also a misleading Marxist trend, according to which the development of technology is determined as a mere reflection of the existing structure of capitalist relations of production. As it is often pointed out, the design and development of technology is socially shaped and determined, on the basis of the already available scientific knowledge and technological infrastructure, but predominantly by the prevailing class structure, the pursuit of certain social interests and the class conflict associated primarily with production. In the contemporary capitalist context, technology is perceived as inherently bearing the imprint of the historically specific, class and exploitative character of the prevailing capitalist relations of production (MacKenzie and Wajcman 1985; Carchedi 1991). This interpretation often tends to social determinism as it focuses on the determinant role of the prevailing relations of production, while denying the significance of the natural and objective conditions of production, or related characteristics in the case of agriculture.

A more adequate approach to the problem would see technology as determined by a dialectical interaction between natural conditions and characteristics, on the one hand, and prevailing social relations of production on the other. It is useful here to recall that the labour process concerns the transformation of natural or intermediate use values, while technology essentially constitutes a mediating instrument in this transformative process between human beings and nature. Nature should be conceived here not in a static and metaphysical sense, but as the changing non-human nature which is continuously extended through human productive activity or intervention. Human beings and labour, of course, constitute part of nature in its wider sense. From the previous basis, it can be argued that technology is not an exogenous but rather an endogenous variable, and this endogeneity of technology should be understood in the context of the dialectical interaction between man and nature, between the natural/objective conditions of production and the prevailing social relations of production or, more specifically, between the forces and relations of production. On the other hand, and as already noted, broadly
technological change implies a transformation of both the forces and relations of production. In a particular natural context and given a particular structure and level of development of productive forces, the social relations of production may play a predominant role in determining the specific character of technology. This should not lead, however, to a social deterministic conception, especially in the case of agriculture, where nature and the characteristics of the sector play a very significant role. Moreover, the development of a certain technology within a specific social and class context should neither automatically imply, nor absolutely determine the exploitative character of technology, given that the class struggle and the transformation of productive relations may play a decisive role in the development and application of the particular technology.

Apart from the dialectical interaction between the forces and relations of production, the state, as a basic political institution, also plays a significant role in the development of technology. It can be argued that this role of the state cannot really escape the overall social and economic shaping of technology (MacKenzie and Wajcman 1985). The basic orientations and policies of the state are determined by the pattern of capitalist accumulation, which in its turn is determined by the internal class structure and the particular manner of integration within the international division of labour (Gulalp 1987). The role and policies of the state towards research and technological development are also determined accordingly. During this century, it has become increasingly accepted that the state should provide not only the technicians and technologists, through the system of education, but also technology itself, where the private sector does not have the capacity or will to do so. For these reasons, and because the small farm cannot afford the excessive economic burden of research and technological development, the intervention of the state is even more necessary for the development of agricultural technology (Goodman and Redclift 1991). State development of research and technology for utilization by the private sector implies, of course, a considerable socialization of the relevant cost, but this is absolutely compatible with the class character of the state itself. In fact this specific character of the state implies that technological development should contribute to the reproduction of the prevailing relations of production. Moreover, and especially under the current conditions of crisis and economic restructuring, the state tends to follow a technological development policy contributing to the improvement of the returns to capital. This concerns both the agricultural-technology-producing industries and the primary agricultural and food-processing sectors, where this technology may be productively utilized. This policy directive partly determines and can explain, to a great extent, the particular forms and development patterns of agricultural technology (e.g., mechanization, pesticides, a specific pattern of biotechnology, etc.). Growing competition and the need to improve the returns to capital are shaping new agricultural technology in such a way as to allow a flexible restructuring of production and a minimization of private cost of production (including labour
cost), while usually increasing the social or environmental cost (negative externalities).

In order to specify more precisely the role of the state in contemporary circumstances, it is also necessary to take into account the internationalization of capital and of the state itself, the differentiation in the scope of its intervention, the legitimation crisis it faces, and the distinction between advanced countries producing technology and less-developed countries, which do not produce technology but are restricted to transferring from abroad and adjusting, to imported technology. My argument regarding the endogeneity and dialectical determination of technology implies that, without neglecting the benefits of international exchange and specialization, the most appropriate technology would develop as an outcome of the internal interaction between the forces and relations of production in a particular country or region. It is well known, however, that international expansion of capital and rapid development of trade and specialization have led to a dependent pattern of development and an externally imposed process of technological modernization in most underdeveloped countries, which usually means the transfer and application of (socially and ecologically) inappropriate technology. Although a partly successful critique has been levelled against the issue of the appropriateness of technology (Howes 1979; Ndongko and Anyang 1981; Bazin 1986), I shall argue, on the grounds of world technological developments outlined above and accumulated development experience, that the issue of economic and ecological appropriateness of technology maintains a crucial significance for all countries and, of course, especially for the underdeveloped ones (Levins 1986). It has been recently argued that this issue can be practically resolved by institutionalization of a participatory process for client-driven research and technology development (Chambers et al. 1989; Merill-Sands and Collion 1993; Ashby and Sperling 1995). Contrary to such expectations, I would argue that available experience and currently observed, socially biased, irrational and environmentally damaging pattern of technology throws into question the effectiveness of any participatory process within a market context. Although the active participation of the producers and agents involved is important at both local and international levels, more fundamentally I would suggest that the viability criteria should be disentangled from the dominant criteria of market competitiveness, the social and class dimensions of the relevant technology should be clearly stated, and the whole issue should be placed not in a narrow national, but in an international framework.

Agricultural restructuring strategies and the process of technological change

It is already clear that technological change may imply a partial restructuring of production, while agricultural and social restructuring in general determine, more essentially, the specific character of technology itself. As noted in the
introduction, there are three main types of response to the current agricultural and ecological crisis. They are closely associated to particular patterns of restructuring of production and associated processes of technological development.

The first is the mainstream drive for further technological modernization, within the existing capitalist framework, aiming at increased competitiveness and production growth. This, however, will most likely recycle existing problems to a higher level, thus exacerbating the current crisis.

A second aims for a social restructuring in the direction of 're-localization,' which rejects modernization and productivism, while emphasizing local development and an endogenous process of technological development. Endogeneity in this case is primarily determined in terms of space and locality (van der Ploeg and Long 1994). So, indigenous development would be the right term to use. This type of response encompasses a great variety of particular approaches ranging from a petty bourgeois resistance to the overwhelming competitiveness of multinational capital or a more specific approach focusing on the advantages of a decentralized and localized process of agricultural and technological development (Marsden et al. 1992; Merril-Sands and Collion 1993; van der Ploeg and Long 1994; van der Ploeg and van Dijk 1995; Ashby and Sperling 1995), to a grassroots radicalism (Esteva 1991) or revolutionary anarchism (Bookchin 1989).

Contrary to an assimilation of historical trajectories, some authors stress agricultural diversity and what has been called "the morphology of today's agricultural heterogeneity" (van der Ploeg 1993).

There are some positive aspects in this broader type of approach. Among these, one could consider resistance to capitalist internationalization (of MNCs), to the repressive and one-dimensional homogenization of internationalized production along exchange value lines, and to the quantitative drive of competitive growth. Moreover, the re-examination of the goals, organization forms and market criteria of viability of farming units, the attempt to develop a socially and ecologically appropriate technology fitting local needs and productive/environmental conditions, and the move towards a more democratic process of agricultural and technological development ensuring greater participation and control by direct producers, could be viewed positively.

The anachronistic attempt to re-establish the role of local communities, the utopian character of some of these particular approaches, and the post-modernist irrationalism in some cases, expressed by an extreme relativism and a negation not only of the logic of capitalist modernization but of any rationality, are negative aspects of the approaches included in this broader context. Furthermore, it could be pointed out that the classless character of the associated theoretical approaches does not allow sufficient specification of the restructuring process, while the fragmentation of localized efforts and inefficient organization of production do not promise effective resistance to the competitive power of international capital (MNCs etc.) or an effective transition to alternative forms of social and production organization (Bebbington 1993). The question of political power is not usually posed and it is not clearly specified whether technological
development should be left to the market mechanism, or a different social process or institutional mechanism. In some cases (van der Ploeg 1993), it is clearly implied that the crisis confronting the contemporary agro-food system is gradually leading to some, still undercurrent and seminal, adjustment processes for the principles of operation and criteria of viability of the units operating in this system. Furthermore, approaches of this type usually neglect the advantages of and the needs for co-operation and exchange on a world level, and their implications for the increase of the productive power of labour as well. It should be noted, finally, that the centrality for some of these approaches of concepts such as 'style of farming' implies the emphasis on an ensemble of structural, institutional and cultural factors, at a concrete local level (van der Ploeg and Long 1994), at the expense of an abstract theoretical analysis of the dynamics of agricultural and social change.

Although, by rejecting both structuralism and extreme particularism or localism, Goodman and Watts (1994, p. 40) correctly point out that "an analysis of agrarian transitions enmired in myriad diversities and specificities provides no greater analytical purchase than the excesses of structuralism," they fail to identify an alternative approach conceptually capable of grasping the essence and the dynamic change of class relations and of the underlying processes of production and distribution of surplus value. Their attempt to transcend the dilemma of structuralism/particularism is rather incomplete as they essentially, and to a large extent, remain in the sphere of phenomenal forms and structural characteristics, and fail to consider specifically the essence of the underlying relations. Thus, they also fail to distinguish clearly, at a more abstract level, the general trends specific to capitalist accumulation from the historical and local configurations of the agricultural and food system.

A third strategic response to the current crisis is associated with a Marxist approach and regards the revolutionary transformation of social production, which negates not only capitalist modernization, but the logic itself and the domination of the capitalist mode of production, and considers technology as an endogenous factor of this transformation process. This type of response or strategy is taking into account some of the positive aspects of the previous approach. It may recognize the need for local development and intermediate steps or medium-range programmes towards a reorientation of technological research and agricultural development, so as to meet social needs, take advantage of cultural elements and traditional practices, and develop an appropriate and ecologically compatible technology. However, taking also into account the shortcomings of the previous approach, it goes further to challenge the capitalist relations of production, which are at the root of the current crisis and largely determining the character of current technological modernization. Finally, negating both the 'modernist Marxist' approach noted above, the relevant experience of the former 'socialist' countries, and the misleading perceptions of social determinism, the proposed approach should point the way forward as far as relevant political economy is concerned, as well as the required
new forms of social organization and technological development. In this sense, a reconsideration not just of the quantitative but also of the qualitative aspects of the productive forces would be expedient for a relevant restructuring of the social relations of production.

The social classes involved in the agricultural sector, among others, will be the active forces in this transformation, while the specific character and rate of transformation will be partly determined by the material basis of the existing agricultural structure and the current restructuring, which reflects two contradictory or partly complementary trends. On the one hand is the dominating trend of capitalist development and agricultural concentration, while on the other hand is a decentralizing trend related to the current capitalist deregulation and other technological or structural conditions. The latter relate to fragmentation of the agricultural labour process in some cases and co-ordination with large-scale capital, which may currently give some opportunities for survival to small-scale production or farming, although in a subordinate role, in the context of an emerging hierarchy of autonomized capitalist concentration reinforcing the traditional pattern of concentration (van der Ploeg and Long 1994; Liodakis 1995).

Conclusions

Attempts to describe the process of technological change or identify the major factors and innovations necessary to promote technological modernization of the agricultural sector, as long as they remain in the context of conventional analysis, usually offer very little for humanity and direct producers. Acceptance of the existing organizational structure and emphasis on technical/production innovations determined by the requirements of the market imply: a) disregard of crucial market failure to ensure sufficient employment and an environmentally and socially viable agricultural economy, b) misplacement of the factors which have led to the international crisis of the agro-food system, and c) neglect or abandonment of domestic or local productive practices and know-how, without taking into account specific social, natural and cultural characteristics.

In this article, the main forms and patterns of technological change in agriculture have been examined, as well as the impact of technological change, within the context of the dominant model of agricultural development and technological modernization. After a critical analysis and assessment of the available theoretical models, I have rejected technological determinism and some particular approaches towards technological change. Transcending both structuralist Marxism and 'modernist Marxism,' I have proposed an alternative Marxist approach, which considers technology as a non-neutral endogenous variable in the development process. The endogeneity of technology is intrinsically related to its dialectical determination by the interaction of the natural or accumulated forces of production and the prevailing social relations of production. The integrity of my argument, and indeed the contribution of this article, rests
partly on the truly dialectical conception of technological change, on the comprehensive understanding of the current crisis of the world agro-food system, which is considered as interconnected with the world over-accumulation crisis of capital, and on the implicit value-theoretical approach which, contrary to a structuralist approach emphasizing only the form of technology and economic relations, implies a dialectical understanding of the intimate relationship between the content and form of these relations.

A critical examination of alternative strategies to respond to the current agricultural and ecological crisis leads us to question both the dominant model of technological modernization, and the medium-range and somehow shortsighted proposal for ‘re-localization.’ What is to be claimed, on a national and international level, regards the preconditions for development of an alternative and appropriate technology. And as I have already noted, the development of an appropriate technology should necessarily transcend the criteria and requirements of the market, pose the class dimensions of the issue, and be based, not on a narrowly local or national, but on an international effort. Appropriate technology should aim at ensuring agricultural employment, economic welfare of farmers and of society at large, protection and upgrading of the environment, and not the maximization of capitalist profit.

This social claim cannot and should not be restricted to the democratization of the process of technological change, the responsibility of the scientific community, and the participatory initiative of farmers and of other social agents involved (Busch et al. 1989; Bebbington 1993; Ashby and Sperling 1995), but should also pose the issue within the context of the overall agrarian question with its necessary implications for the required social change. And this, of course, because the issue of technological development of the agricultural sector cannot be considered as independent from the overall organization and transformation of society. In this sense, therefore, the contribution of the present article lies in challenging the re-localization argument and the idea that the necessary agricultural restructuring and client-driven research, aiming at the development of an appropriate and environmentally compatible agricultural technology, could be effectively accomplished through the market mechanism.

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