THE NEED OF CONSERVING FARMLAND TO MEET THE DEMAND FOR FOOD

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Abstract

Increasing food production to feed the millions of hungry people added to the world population each year remains a critical issue of concern for many governments and international organizations. Several courses of action have been proposed to meet the needs for food: increase the amount of land under cultivation; increase the yields on currently cultivated acreage; increase the output from oceanic fisheries; reduce post-harvest losses; put on the demographic brakes; preserve the farmland under cultivation.

The present paper focuses on the first and last propositions and explores the potentialities and risks associated with each of them in an effort to tackle the food problem. The objectives are four-fold: a) to explore the impacts placed upon presently cultivated land from erosion, salinization, desertification, overgrazing, residential, recreational and industrial development, and other ecologically unsound land use practices, b) to call the attention for the devastated consequences of careless and short-sighted land use practices, c) to examine the possibilities of bringing more land under cultivation to meet the increasing demand for food, and d) to stress the importance of the human capital as the main resource input in the production of more food.

Athough the authors are not pessimistic about our ability to meet the food requirements, they do not espouse the solutions that rely on technocratic assumptions. Even if solutions can be provided by science and resources can be mobilized to put forward the necessary projects, their success can be strongly questioned when an equal attention has not been paid on the need for social, structural and institutional change in those societies where increases in food production are mostly needed.

Résumé

L'exigence d'accoître la production alimentaire pour satisfaire les besoins d'une population mondiale croissante reste un problème crucial pour les gouvernements et les organisations internationales. Différentes actions ont été proposées pour satisfaire les besoins alimentaires: accroître la superficie des terres cultivées; augmenter le rendement sur les surfaces cultivées; accroître la production de la pêche océanique; réduire les pertes après-récolte; freiner l'accroissement démographique; sauvegarder les terres soumises à culture.

Ce rapport examine en particulier la première et la dernière proposition et il explore les potentialités et les risques qui y sont associés en vue d'aborder le problème alimentaire. Quatre objectifs sont poursuivis: a) explorer les impacts, sur les terres actuellement cultivées, de l'érosion, de la salinisation, de la désertification, du surpâturage, du développement des structures résidentielles, de recréation et industrielles, et d'autres utilisations de la terra qui ne respectent pas l'environnement, b) attirer l'attention sur les conséquences dévastatrices d'une utilisation des terres aveugle et négligente, c) explorer les possibilités d'étendre les superficies à cultiver pour satisfaire la demande alimentaire, et d) souligner l'importance du capital humain en tant qu'entrant principal pour accroître la production de denrées alimentaires.

Même si les auteurs ne sont pas pessimistes sur notre capacité de réussir à satisfaire les besoins, ils n'embrassent pas les solutions basées sur des hypothèses technocratiques. Malgré la possibilité de rechercher des solutions scientifiques ou de mobiliser des ressources pour la réalisation des projets nécessaires, le succès de ceux-ci serait fortement douteux si on ne tient pas suffisamment compte des besoins sociaux, structurels, et aux changements institutionnels dans les sociétés pour lesquelles l'augmentation de la production alimentaire est extrêmement urgent.

Since the domestication of animals and plants, some 10 thousand years ago, until today, food production depends exclusively on the farming of suitable areas of land. On such fertile agricultural lands great civilizations have been developed throughout human history (Mesopotamia, Phoenicia, Egypt etc.) and control over fertile valleys was the main, if not the exclusive, reason for long and devastated wars. Even contemporary struggles between countries do not turn around ideologies or national prestige but around the control of natural resources and often productive agricultural land.

At the present century despite the enormous progress in technology applied to agriculture, the quality and suitability of agricultural land is the prime production input that determines, to a great extent, the production output (Daoutopoulos, 1981). Crop production uses more land than any other human activity.

In this paper we consider the various factors involved in conserving good quality agricultural land in order to meet the world demand for food. We, therefore, examine the physical and economic properties of land, the factors decreasing farmland, the obstacles in bringing more land under cultivation, and the ecological consequences of agriculture upon natural systems.

The food problem

Today, food is not abundant as it was never so throughout human history. The prospects for the world food situation in the 2000's are not very optimist. Food reserves are not enough to feed the world population and starvation kills 50,000 people every day (UNDP, 1981). Brown writing on the need to launch the Environmental Revolution emphasized the continued decline of grain production per person since 1984 by 1 percent a year (Brown, 1992:175).

The main reasons for the increasing scarcity of food are two. The continuing population explosion in the "developing" nations and the rising affluence in the "developed" ones. After millions of years of very slow growth, the world population

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grows explosively in the present century. The first billion of world population took some 2 to 5 billion years to be attained by 1800 AD, while the fifth took 12 years (UN and Durand, 1977). Adding the next billion will take only about 10 years (probably by the end of this year) (UNFPA, 1992).

World food production increased by 140 percent between 1956 and 1988 and kept ahead of population growth on all continents except Africa and Latin America. As a result, average food production per person increased by more than 25 percent between 1950 and 1988, even though world population increased by nearly 2 billion. The impressive increases in world food production disguise the fact that average food production per person declined between 1950 and 1988 in 43 LDCs (22 in Africa) containing 1 of every 7 people on earth. The largest declines have occurred in Africa, where average food production per person dropped 21 percent between 1960 and 1988 and is projected to drop another 30 percent during the next 25 years (Miller, 1989). By the year 2000 at least 64 of the world's 117 LDCs (29 in Africa) will be unable to feed their projected population from their own water and land resources or from resource exports.

Given the dramatic increases in the demand for food, in the near future, it seems important to consider what courses of action are left open to humanity. Eight are the major alternatives (Brown and Eckholm, 1974; Larkin et al., 1981; UNDP, 1981):

a) increase the amount of land under cultivation,
b) increase the yields on currently cultivated land,
c) increase the output from oceanic fisheries,
d) reduce post-harvest losses,
e) put on the demographic brakes,
f) encourage simplification of diets among the affluent,
g) preserve the farmland under cultivation.

While no one would object the necessity to put on the demographic brakes, objections would arise for several other courses e.g. the first three that call for an increase on the ecological pressures placed upon the environment. Of course each one of the proposed pathways calls for different policy actions and some might be superfluous for certain countries or areas, e.g. increase in the amount of land under cultivation. Thus, for each particular country a plurality of pathways, different from those adopted in other countries, might be the answer. In addition, a multi factor approach diminishes the risk associated with too much emphasis placed on a single course of action. What is left out from the above list of actions that are technologically oriented is the lack of an equal attention to the social, structural, and institutional changes needed in many "developing" countries where food is mostly needed.

Land as an input in agriculture

Although land comprises roughly 30 percent of the earth's surface only two-fifths of the earth's total land is habitable by humans and has physical and climatic conditions permitting the growth of crops. The rest is too wet, too dry, too warm, or too cold, or too acidic or alkaline, too rocky or sandy, or covered with urban settlements (Larkin et al, 1981). Furthermore, soils presently farmed do not have the same productive capacity. Land used in agriculture must have certain properties (physical and economic) that determine to a great extent production alternatives and cost.

Physical soil properties

Soil physical properties are of prime importance to agriculture since soil is not a neutral matter for plants but a complex living world in itself. There is a great variety of soils since they emerged through the degradation of various rocks under various climatic conditions and in a very slow process over thousands of years. As a result, soils differ in their characteristics not only from region to region but also within each region, from one field to another, and even within each field. Soil physical properties that are of prime importance to food production are:

a) *topography*: steep slopes are difficult to cultivate with machinery and control of soil erosion is problematic,
b) *aeration*: ability to provide air to plant roots and to organisms growing in the soil,
c) *water intake and retention*: ability to capture and hold water that is so crucial for plant growth,
d) *soil acidity*: high soil acidity greatly reduces root growth,
e) *impedance to roots*: presence of cemented zones prevent root penetration into subsoil and result in poor plant growth,
f) *clay content*: large amounts of clay restrict root growth and lead to crusting that prevents emergence of seedlings,
g) *humus content*: promotes desirable physical and chemical properties of soil by providing the life base for a diverse population of beneficial to plants organisms and acting as a storehouse for plant nutrients. Also, humus increases the ability of soil to retain water.

Economic properties of land

Land use problems are closely associated with two basic characteristics of land: immobility and finite (Davis, 1976). Immobility, can be further classified into physical and economic immobility. Physical immobility, refers to the fact that land remains where it is and thus forms the basis for establishing ownership. On the other hand, economic immobility refers to the fact that land used for a particular purpose cannot be transferred easily to another use. For example, farmland is the most mobile use of land since it can be used for the production of various crops, for residential, recreational, and industrial development etc. Once farmland is converted to non farming uses, its mobility is reduced drastically since this conversion is almost irreversible. Finite refers to the fact that land is not reproducible. Of course over time, accretion and loss of land takes place through geological processes but this is negligible compared to the increasing number and needs of people competing for its control.

Factors decreasing farmland

Several factors contribute each year to substantial losses of farmland. Arms (1990) estimates that each year eleven million hectares (ha) of land become unfarmable as a result of erosion, desertification, salinization, and conversion to non-agricultural uses. If the present trend continues we might loose about, one third of the world's cropland by 2025. Of course the area lost is not evenly distributed among "developed" and "developing" countries and the importance of each factor is not the same throughout the world. Therefore, ranking these factors in terms of importance is not possible and will not have a universal validity.

Residential pressure upon farmland

The rapid growth of cities all over the world creates a dramatic impact on the adjacent agricultural lands. Cities in Latin America are typically growing at more than 4% annually, with some increasing at a higher rate. Projections for the world's urban population made by the United Nations reveal alarming dimensions. By the end of the present century over 40 percent of Africa and Asia (excluding Japan) and 76 percent of Latin America will be urbanized (UNFPA, 1992:3).

In USA, several estimations revealed the magnitude of farmland conversion due to residential development. In Michigan, between 1974 and 1979, 364,225 hectares of farmland were converted to shopping malls, residential and commercial and other non-food producing uses (Struthers et al, 1981). In California, for every 1000 persons added to the population, 97.1 hectares of cropland, on the average, are covered with buildings, streets and sidewalks. Up to 1960, 1.2 million hectares of farmland were converted to non-farm uses. Up to 2020 this area is expected to increase to 5.3 million hectares, half of the presently farming area. If the present trend continues in the future, California will not be able, not only to export food but to feed its own population (Ehrlich and Ehrlich, 1970).

Residential development has two other serious side-effects. First, increases land val-

ue and places immense pressure on farmers to sell their land to developers. Especially on the urban fringe, where property values are the highest, farms are lost to development at the highest rates (Struther et al, 1981). Second, frequently takes the form that has been termed "leap-frog development" where farms are suddenly surrounded by residential projects and nuisance suits brought by the new suburban neighbors that force farmers to sell their farms. The US Assistant Secretary of Agriculture Robert Cutler once observed that "asphalt is the land's last crop" (Arms, 1990). Worldwide, every year about 6 million hectares of farmland disappear under houses, mines, roads, reservoirs, factories, and power plants.

Decline in soil productivity

The ability of soils to produce food is not maintained indefinitely. This was the first lesson that early farmers learned from nature. Their reaction to this was the practice of shifting cultivation (e.g. slush-and-burn agriculture, fallow period). As population pressure upon land increased, the fallow period was shortened and sometimes abolished entirely with dramatic effects upon the productivity of the land (erosion). Advances in agronomy, mostly during the present century, gave farmers the opportunity to replenish the nutrients removed from the soil by crops and thus to maintain high yields with no need for extended fallow periods. Recent studies have revealed that the application of chemical fertilizers and other modern farming implements have not overcome the problem of maintaining soil productivity and in most cases have created severe side effects (pollution and eutrophication of lakes and inland waters). Three are the main factors associated with the long-run decline in soil productivity: continuous cropping, irrigation, and erosion.

Continuous cropping or monoculture

Although quite early in the history of plant cultivation, the beneficial effects of crop rotation were discovered, during the last half of the present century, rotation gave way to continuous cropping or monoculture. Some farmers believe that monoculture can continue indefinitely thanks to chemical fertilizers and pesticides. Unfortunately, those inputs cannot overcome the problem as a result of: a) diseases build up in the soil and the environment to the point that they cannot be easily controlled (Borgstrom, 1973), b) soil fumigation destroys several desirable organisms (earthworms and other soil organisms, nitrogen fixing bacteria), and c) each crop draws from the soil different quantities of nutrients (**table 1**) so that the mineral content of the soil is utilized more completely only under crop rotation. In addition, higher yields become progressively difficult to obtain as a result of the law of diminishing returns.

Table 1 ***Macronutrients removed from soil by various crops (Kg/hectare).***

Crops	Nutrients				
	N	P	K	Ca	Total macronutrients removed
Wheat	85	16	47	13	161
Corn	174	28	58	24	284
Sugarbeets	146	26	179	47	398
Alfalfa	174	18	123	134	449
Potatoes	224	9	247	58	538
Tomatoes	180	25	280	152	637

Source: a) Fried and Broeshart 1967:120-126.
b) Conversion to metric by authors.

Salinization

Irrigation schemes to foster agricultural production often run into ecological troubles. The plain between the rivers Tigris and Euphrates, known as Mesopotamia, was the oldest irrigated area in the world and the place where the first human civilization flourished some six to seven thousand years ago. As Eckholm (1976) pointed out, the end result of six millennia of human management is not an encouraging observation since what is left today is a desert.

Saline soils make the soil solution sufficiently concentrated to injure plants and impair soil productivity (Hansen et al, 1980). Salinity is a major problem in arid regions where irrigation is mostly applied and needed to foster food production. Soils in those areas that were free from excess salts before cultivation have been rendered non-productive by the use of irrigation water containing excessive quantities of salt. Where drainage is not provided, the irrigation may add as much as 3 to 25 or more tons of salt each year to an hectare of land (Hansen et al, 1980). In Africa, for every hectare of new land brought into cultivation by irrigation, another hectare of already cultivated and irrigated land goes out of cultivation as a result of salinization brought by irrigation (Arms, 1990). In order to prevent salt accumulation and consequent decrease in crop yields farmers must remove as much salt as they brought in by means of water passing through the root zone. Unfortunately the problem will become even worse in the future since farmers will try to irrigate as much area as possible with increasingly limited water supplies. As a result, water will not be enough to wet the soil beneath a few inches, leaving all the salt that was brought within the root zone.

Another type of soils that have excess amount of salts are the so called "alkali" soils. Alkali soils call for chemical and physical improvements in order to be reclaimed. Yields of alkali soils in the arid western areas of the United States have been reduced by about 20% and occasionally abandonment of the land was the end result.

Soil erosion

Soil erosion is the first and most deleterious impact of agriculture on the environment (Tive, 1991) and the land itself. Soil erosion by wind and water is taking alarming dimensions especially in many developing countries of Asia, Middle East, Africa, and South America. As population pressure upon land increases, farming expands to hillsides where the thin mantles of topsoil cannot sustain continuous and intensive cultivation. The uneven distribution of rainfall throughout the year, accompanied with bad farming practices results in the removal of the thin topsoil in a few years. Local forests are upon heavy pressure due to fuel demands for heating and cooking that exceeds their replacement capacity. At the same time overgrazing by goats and sheep has the same or even worse effects upon the soil. Although it takes centuries to form an inch of topsoil through natural processes, in some areas of the world man is managing to destroy it in only a fraction of that time (Brown and Eckholm, 1974).

Soil erosion in Greece is nothing new. It is as old as man's presence on this land. As Wagner (1978) pointed out:

"A surprising amount of land in Greece originally supported thin, open forests with a good growth of grass on the mountain slopes and shrubs and grass on the plains. Homer, writing around 900 BC, mentioned wooded Samothrace and the tall pines and oaks of Sicily. Five hundred years later, Plato remarked in the Critias that: The parts, therefore, that are left at present are but as small islands, if compared with those that existed at that time; and may be said to resemble the bones of a diseased body; such of the earth as was soft and fat being washed away, and a thin

body of the country alone remaining". Holeman (1968) reviewing surveys dealing with the sediments yield of major rivers around the world estimated the annual sediments yield per continent and concluded that Asia yields about 79 per cent of the sediment reaching the oceans annually (**table 2**). Of course a substantial part of that sediment yield may be attributed to the population pressure in Asia where 83 percent of the available land is under cultivation and overgrazing, and hillside farming along with unsound farm practices prevail. Brown (1984) has estimated 1970 global erosion at $14x10^9$ tonne yr^{-1} compared with $11x10^9$ in prehuman times.

Table 2 ***Annual sediment yields by continent.***

	Measured annual sediemnt yields of rivers to oceans		Total sediment yield to oceans extrapolated from measured data		
Continent	Measured drainage area (km2)	Annual suspended drainage discharge (tons per km2)	Total area draining to oceans	Total annual suspended sediment discharge (10,000 tons)	%
N. America	6,383,441	95	20,720,000	1,960	9.7
S. America	9,894,758	62	19,425,000	1,200	6.0
Africa	8,149,901	27	19,943,000	540	2.7
Oceania	1,073,840	44	5,180,000	230	1.1
Europe	3,515,555	35	9,324,000	320	1.6
Asia	10,911,229	521	26,936,000	15,910	78.9
Total	39,928,724	201 (aver.)	101,528,000	20,160	100.0

Source: a) Holeman (1968).
b) Conversion to metric by authors.

Surface mining

According to the US Department of Interior (1971) surface mining takes several forms, like: open pit mining (quarry, open cast); strip mining (area, contour); auger mining; dredging; and hydraulic mining. Due to the development of gigantic machinery that have lowered tremendously the cost of exploitation, surface mining became the most predominant type of mining. It is estimated that in the United States by 1964 fourth-fifths of total production of ore and solid fuels came from surface mining. Besides those on-side effects there are several off-site effects: destruction of the protective vegetative cover; stream and underground water pollution; isolation of large areas by steep high walls; destruction of the natural environment (economic and aesthetic values); increased erosion; sedimentation of rivers, streams, and lakes; alteration of normal and sub-surface drainage patterns; etc. The Bingham Canyon copper mine, Utah, USA affects an area of over 7 sq. km and has been excavated to a depth of 774m. The Zheleznogorsk iron ore mine in the former Soviet Union has created a hole 3 km long and 500m wide that is still expanding (Tive, 1991).
The US Department of Interior admits that only one-third of the total area disturbed has been adequately reclaimed (either by natural forces or man's own effort) while two-thirds (about 0.8 million hectares) still require some remedial action. Unfortunately, we lack data on the amount of prime land destroyed and whether reclamation is able to restore the fertility of the land to its prior levels. The US Department of Interior admits that there is no consensus among professionals in many scientific disciplines upon what is an adequate reclamation for those areas. The impacts of surface mining are expected to be even worse in other countries where environmental conservation is very poor.

Expansion of industrial sites

Expansion of industrial complexes and establishment of new plants is always at the expense of farmland. The relative lower ratio of land investment to their overall investment, puts agriculture in a very difficult position in the land market (Daoutopoulos, 1981). Unfortunately, we lack data on the amount of land lost to industrial activities. What is very important to emphasize is not the actual area of agricultural land occupied by an industrial complex but the impetus created for the attraction of other industries, services and new residential areas.
The population turn-around in the United States is associated, among other factors, with the transfer of the industry and the establishment of new factories in the rural areas. It is not risky then to conclude that the decentralization of the industry has converted in an irreversible way a portion of the farmland, brought up farmland prices, and provided the impetus needed for more land to be converted in the near future. Zoning was put into effect in several "developed" countries as an answer to the detrimental effects of uncontrolled location of industries. Unfortunately, such regulation is lacking in the "developing" countries who are sometimes eager to provide anything needed to attract badly needed foreign investments.

Dams

Energy shortages along with shortages in fresh water for irrigation, and urban and industrial consumption will provide the impetus needed to impound and control all of the wild rivers. The world's potential production of hydroelectric power is roughly equivalent to the amount of power now produced by fossil fuels. On the other hand, agricultural production can increase only if water can be provided to plants when it is mostly needed. But the construction of dams to harness the hydraulic power and control the flow of water for irrigation and water supply schemes will have some serious side effects.
First, dams eliminate pieces of productive farmland depending on the size of the lake created. The High Aswan Dam submerged the valley for about 400 miles upstream including sites of great archaeological value and necessitated the transfer of about 90,000 Egyptian and Sudanese peasants to new agricultural settlements. In the United States it is estimated that flooded area due to the construction of dams will increase from 4.9 million hectares in 1970 to 8.1 million hectares by the end of the present century (Wagner, 1978).
Second, construction of dams can create severe ecological problems that may outweigh benefits. One classical example, often cited in the literature, is the construction of the Aswan High Dam. It did not only increase the irrigated area of Egypt by one third but it caused several severe environmental side effects:
a) The annual catch of sardines in the Nile delta fell from 18,000 tons to 500 tons after the dam was built.
b) Without the annual silt deposition in the Nile valley, it is estimated that it would cost over $ 100 million per year to produce enough fertiliser just to replace the nutrients in the silt now being trapped annually in Lake Nasser (Wagner, 1978).
c) The Nile delta has ceased to grow and begun to erode threatening to ruin millions of hectares of cultivated land by making them saline extensions of the sea (Ibrahim, 1987).
d) At the same time, river banks are eroding and 550 bridges are in danger of being destroyed by the clear, fast-flowing river (to save these structures, 10 more barrages must be built at a cost of $ 250 mil-

lion (Levine, 1975).
e) The introduction of perennial irrigation creates conditions that are ideal for the spread of the serious parasitic disease bilharzia (schistosomiasis) (Ehrlich, and Ehrlich, 1970).
f) Soils along the river located in higher elevations, formerly irrigated in the flood season, cannot be watered now without the use of motor pumps (Ibrahim, 1987), and
g) Dams are not constructions for an indefinite use. Siltation will gradually render them useless.

Transportation

The construction of new airports, seaports, highways, and railways removes another portion of land from agriculture. In the United States, 62,160 square kilometers are covered by roads and their rights-of-way (Mowbray, 1969).
While highways and railways take up a relatively small strip of land as they pass through agricultural areas, airports demand a substantial adjoining area of flat land that comes totally at the expense of agriculture. Twenty years ago the world community was astonished by the aggressive feelings of Japanese farmers against the Narita airport in Tokyo. The same scenery was repeated in Athens where farmers strongly opposed the construction of the new airport in Spata. Government and juries that intervened based their judgement upon the public interest that has to be above the interests of any group. But the main argument was whether public interest was better served by the construction of the new airport at the expense of agriculture or by the preservation of good farming land.
Besides their direct effects upon farmland, transportation projects have several other side effects. First of all, they attract several non-agricultural activities that have a much higher impact on farmland decrease. Second, during the construction stage, erosion can become a major problem. Erosion can be a problem also after the construction when poor design has created steep cuts that do not only look ugly but defy revegetation. Mumford (1970) has given a very pictorial description of those man made projects:
"Perhaps our age will be known to the future historian as the age of the bulldozer and the exterminator; and in many parts of the country the building of a highway has about the same result upon vegetation and human structures as the passage of a tornado or the blast of an atom bomb".

Increasing the amount of land under cultivation

The present analysis of factors contributing to the decrease of farmland acreage and productivity will not be complete unless an equal attention is paid to the possibilities of increasing food production by bringing more land under cultivation.

Recent estimates (**table 3**) indicate that the world's potentially arable land is about 3.19 billion hectares which is slightly twice the area of land presently cultivated. Thus, one can conclude that humanity has enormous land resources to expand food production and therefore decreases in the area of presently cultivated land do not pose any threat. Estimates of how much additional land can be brought under cultivation vary widely and they are not useful because none specifies the associated cost to reclaim and to maintain into production. Several other arguments that will be developed immediately cast strong doubts on the assertion of almost abundant land resources and thus, it is wise to use our present resources more carefully than we did in the past.

Obstacles in bringing more land under cultivation

Although the presently cultivated land is less than half, specifically 44 per cent of the potentially arable land (Table 3), significant differences exist among the continents and even among the various nations. In Europe and Asia only very limited area of land can be brought into cultivation since 88 per cent and 83 per cent respectively of the potentially arable land is presently cultivated. Thus, Asia who mostly needs additional pieces of land to expand its food production (only 0.18 hectares per person, the worst among continents) is unable to do so.

Table 3 ***Present population and cultivated land on each continent compared with potentially arable land.***

Region	1985 Population (millions) (a)	Land			Cultivated Land per person (hectares)	(4)/(5) x 100
		Total	Potentially Arable area (billions of hectares)	Cultivated (b)		
	(1)	(2)	(3)	(4)	(5)	(6)
Africa	551	3.02	0.73	0.16	0.29	22
Asia	2829	2.74	0.63	0.52	0.18	83
Oceania	24	0.82	01.5	0.02	0.83	13
Europe	492	0.48	0.17	0.15	0.30	88
North America	400	2.11	0.47	0.24	0.60	51
South America	271	1.75	0.68	0.08	0.30	12
Former USSR	278	2.23	0.36	0.23	08.3	64
Total	4845	13.15	3.19	1.39	0.29 (avg.)	44 (avg.)

Source: The World Food Problem, report of the Panel on the World Food Supply, President's Science Advisory Committee, The White House, May 1967, Vol. II, Table 7-9 p. 434 and Snodgrass, and Wallace, 1975: 385.
a) Mid-1985 population estimates of the Population Reference Bureau, World Population: Toward the Next Century, Washington, DC.
b) Saem as FAO "arable land and land under permanent crops". It includes land under crops, temporary fallow, temporary meadows for mowing or pasture, market and kitchen gardens, fruit tress, vines, shrubs, and rubber plantations.
Original data in acres were converted to metric by authors.

Uneven distribution of available land

Available pieces of uncultivated land are unevenly distributed among continents and nations. Even worse, countries who mostly need food do not have substantial areas to bring under cultivation. Oceania and former USSR are more rich in land resources since they have the largest man/-land ratio (0.83 hectares per person). Asia and Africa are the poorest with 0.18 and 0.29 hectares per person respectively.

Lower productivity of uncultivated land

Land presently cultivated is the best of all available land for food production. Additional land can be brought into production only under heavy investments and frequently the high risk on those investments would make governments and international organisations very reluctant to pursue such projects. Several intervening factors are responsible for lack of success in bringing more land under cultivation and thus need a thorough consideration.

Implications of bringing Tropical lands into farming

More than half of the potentially arable land lies in the tropics while most of the currently cultivated land is in the cool temperate zones (Snodgrass and Wallace, 1975). There are several severe implications of bringing tropical lands into farming and it is wiser to leave tropic forests in tact. Once trees are removed, the soil is exposed to the direct radiation of the sun. Soil temperature is rising rapidly to levels that put an end to the microbial life that convert organic matter into humus and through which nutrients are made available to plants. At the same time, heavy rains wash out the top layers of the soil, humus and water soluble plant nutrients, decreasing the fertility to such minimum levels that cannot support plants for more than two years. Massive amounts of fertilizers are needed to replace the constantly removed nutrients, resulting in an increased cost of farming. In addition, high temperatures and high levels of humidity create favorable conditions for the various pests and diseases that cannot be easily controlled. Brazil's experience from the development of the Amazon's basin should become a lesson to those dreaming to turn tropic areas into the bread-basket of millions of hungry people. Wagner (1978) explains why such a project is a mere utopia:

"... despite the influx of millions of settlers from arid north-western Brazil, the results have not been the integration of expanded agriculture into Brazil's national economy but rather the extension of subsistence farming into a new region. Nearly 2 million people have settled along the 930-mile Belem-Brazilia highway, but most depend on food produced elsewhere. ... Far from being the economic mainstay of the Brazilian economy, Amazonia contributes only 1 percent of the gross national product while requiring 3 percent for its maintenance. It is extremely unlikely that the Amazon basin will ever be successfully used for conventional crop farming".

Need for irrigation

Water is a crucial component in the effort to bring more land under cultivation. According to Time magazine (1990) food supply has kept pace with population growth only because irrigated land has doubled in the past three decades. As Snodgrass and Wallace (1975) emphasized "about 11 percent of the potentially arable land in the world needs irrigation to grow even one crop".

Bringing water to irrigate more land calls for projects that are costly, take time to develop and upset the balance of nature. At the same time, operation of these projects and the timing and amount of water applied to crops calls for organizational capacities and skills that are lacking among the administration and individual farmers in many developing countries (Willett, 1976). In addition, water is a limited factor and in the near future could become the catalyst for armed conflicts (e.g. Middle East, Egypt-Ethiopia, India-Bangladesh). Africa, the continent that needs irrigation the most, has the lowest potential for it because of the remote location of its major rivers and its unfavorable topography and rainfall patterns.

Fertilizer needs

Bringing more land under cultivation calls for enormous increases in the production of chemical fertilizers. Price of fertilizers has been increased rapidly during the 70's due to steep rises in coal and oil prices. As a result, farmers in the "developing" countries who would benefit mostly from the increased use of chemical fertilizers, in old and new lands, are the least able to afford them. In addition, due to the fact that the fertilizer industry is energy intensive and some of the resources used are not renewable (phosphates), it is doubtful whether such high production of chemical fertilizers can be sustained indefinitely. The following estimates (Snodgrass and Wallace, 1975) give an idea of the resources needed to meet fertilizer needs:

"To keep food production growing at a pace equal to that of population, it is estimated that fertilizer usage should increase to 34 million metric tons by 1985 and 67 million metric tons by 2000. To achieve the needed increase in fertilizer by 1985 will require a $17 billion investment, plus an additional annual cost to farmers of $9 billion".

Economic and nature costs of development

Bringing new land under cultivation requires the construction of roads, clearance and removal of bushes, trees and stones and other necessary actions that would create severe conflict with world nature conservation needs and will be very costly.

Cultural and institutional constraints

Bringing more land under cultivation is not only a matter of resources. The people in those areas constitute the most important resource that will be called to utilize the other resources (land, labor and capital). Under-utilizing the human resource potential i.e. lack of incentives for farmers to adopt the full combination of technologies needed, lack of adequate education and skills, lack of effective and socioculturally adapted extension organizations, etc. threatens to a great extent the success of bringing more land under cultivation.

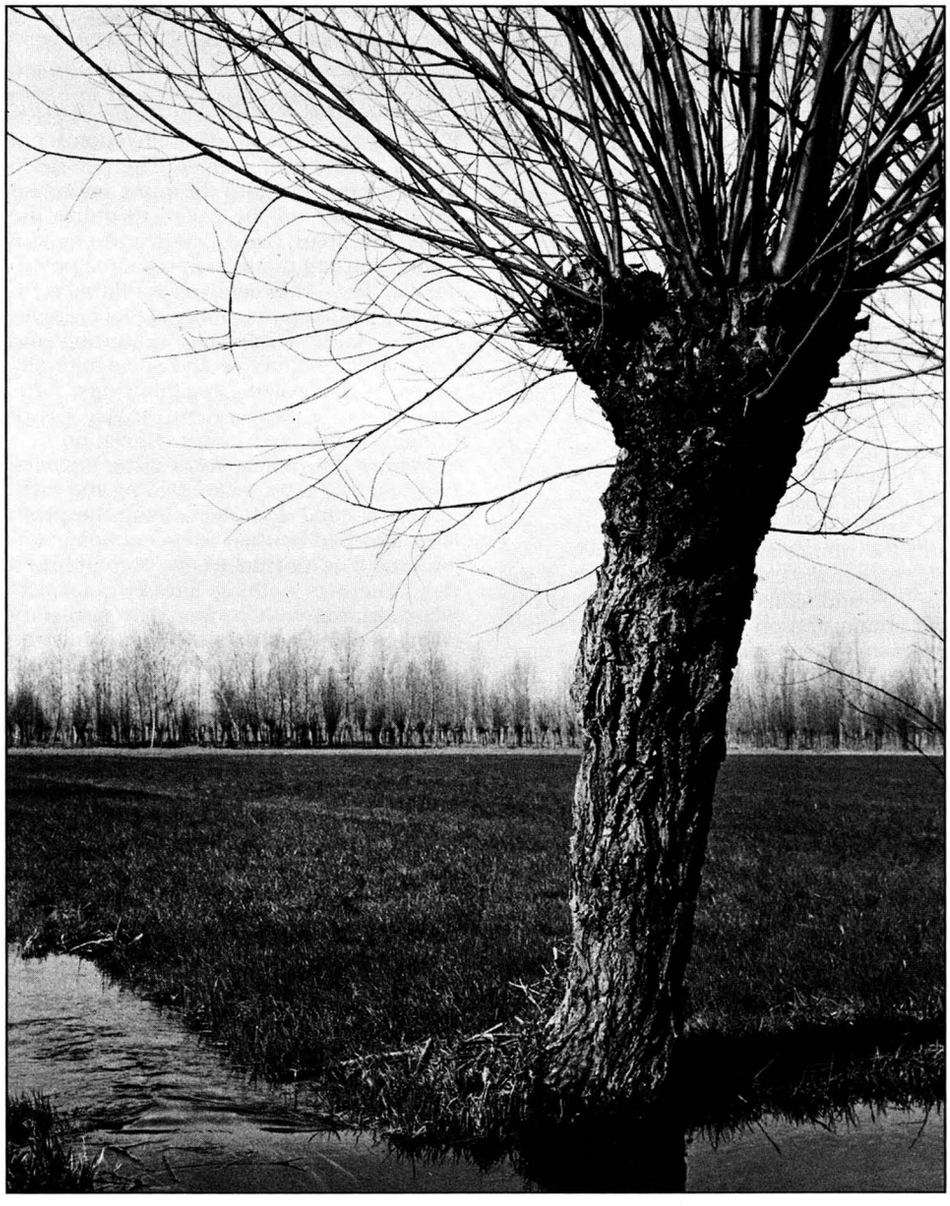
Preparing the people for a more effective utilization of resources, building the institutions needed and overcoming the problems imposed by their socio-economic environment is not an easily accomplished task. There is nothing like a "quick fix" when dealing with people. The necessary changes come with a slow pace while the demand for more food is steadily increasing.

Agriculture in ecological retrospect

Although man is a species within the world's ecosystems, his impact upon nature has reached a point that catastrophic consequences may arise. There are clear signs that today's agricultural systems are unsustainable. Topsoil is being depleted, forests are disappearing and numerous wild species are being driven to extinction. The World-watch Institute estimates that one-sixth of annual grain production is based on unsustainable use of soil and water.

One of man's main impacts is the simplification of the ecosystems through the practice of farming. Complex ecosystems able to sustain indefinitely hundreds of species in a small area through balanced exchanges have been simplified to a few plants and animals. As research on succession has revealed man's intervention runs contradictory to nature. While nature's strategy is towards achieving a high total biomass / total photosynthesis ratio (B/P), farmer's goal is towards the reverse efficiency -a high P/B efficiency (Odum, 1969).

Single crop agriculture greatly increases the production and efficiency of plant production, but also increases the probability of an ecological disaster. An area covered by a single crop and infected by a disease would have as a result the total loss of the production as happened several times in the past (Rhoads, 1991). On the contrary, a mature ecosystem e.g. a tropical rain forest, through the complexity of relations developed among its species has the ability to withstand a loss of a species without the collapse of the entire ecosystem. This is one of the main arguments against ex-



panding the arable land since such practice will result in the simplification of ecosystems in a much wider area than presently.

Ehrlich and Ehrlich (1970) have presented several statistics that associate man's activities with the great increase in the amount of desert and wasteland:

"In 1882 land classified as either desert or wasteland amounted to 9.4 percent of the total land on Earth. In 1952 it had risen to 23.3 percent. During the same period land classified as carrying inaccessible forest decreased from 43.9 percent to 21.1 per cent. The vast Sahara desert itself is largely manmade, the result of overgrazing, faulty irrigation, deforestation, perhaps combined with a shift in the course of a jet stream. Today the Sahara is advancing on a broad front at a rate of several miles per year. The great Thar Desert of Western India is also the result of man's influence. Some 2000 years ago, what is now the center of this desert was a jungle".

Several other aspects of modern agriculture pose certain ecological risks: First, one of the main ways for increased food production was the introduction and diffusion of high yield varieties. Until recently, several scientists believed that the answer to food shortages is the replacement of native crop varieties with high yield varieties, an effort that lead to the "Green Revolution". Today, it is recognized that such a strategy is associated with high economic and ecological risks since it is one further step to the simplification of ecosystems (Rhoads, 1991) for the following reasons: First, high yield varieties are more vulnerable to climatic changes and diseases and their world-wide application would eliminate the native genetic material. Recognizing the importance of the problem, FAO has assisted local agricultural research stations, all over the world, in establishing genetic storage banks in order to preserve native varieties developed through thousands of years of natural selection.

Second, introduction of high yield varieties must be accompanied by the application of fertilizers, if substantial increase in crop production is expected. Then, besides the economic investments, the problem of eutrophication of lakes and other inland waters, arises.

Third, insecticides widely applied in modern agriculture besides being direct threats to human and other living organism's health, are among man's most potent tools for simplifying ecosystems. Wagner (1978) proposed to call these synthetic compounds as "biocides" instead of the misleading terms "pesticides" or "insecticides" since they do not kill selectively the pests or insects in the fields.and they do not restrict their harmful effects on them alone. Instead, due to their persistence pesticides enter food chains and with each upward step they become highly concentrated (bio-magnification), thus having unexpected effects in the ecosystem far beyond the original intent of those who first introduced them into the environment. Extensive research on DDT, the first widely used insecticide, has documented its harmful effects on fish and birds. Another implication of insecticides is that insects exposed to them are becoming immune or resistant. In addition, insecticides kill also the beneficial insects (predators of the pests), making the situation even worse after a few years of their wide application. Wagner (1978) cites how farmers in the Canete Valley (Peru) were caught in this non-ending war against pests.

"Modern organic-synthetic biocides were introduced between 1949 and 1956 to control seven major pests on the chief crop, cotton. At first the yield of cotton increased, from 455 Kgs per hectare to 727 Kgs per hectare. But by 1965 the yield had dropped to 332 Kgs per hectare and major pests had increased from seven to thirteen, several of them highly resistant to the biocides. Worst of all, the lowered yield of cotton plus the increasing frequency and expense of biocide application was driving the farmers into bankruptcy".

Scientists who recognized those problems have now turned their efforts in developing programs that place less emphasis on organic chemicals. Development of resistant crops, cultivation methods, and introduction of predators, parasites and pathogens (biological control) along with a limited use of organic chemicals are the components of this new approach to pest control (Integrated Pest Management).

In the 1980's, the issue of "sustainable agriculture" began to be considered by several international organisations. The Consultative Group on International Agricultural Research (CGIAR) defines sustainability as the "successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources".

Conclusions

The preceding analysis has revealed two main points: First, the continuous restriction of farmland due to residential, recreational, and industrial development, to transportation, etc. The farmland lost is the most valuable because we usually build in valleys where most productive land in contained. Of course the conclusion to be reached is that conservation of farmland does not imply necessarily the complete elimination of those land uses. Those alternative uses of land are so much embedded in our culture that many people will oppose any policy action that places severe restrictions. What is mostly needed, in the short-run, is to become aware of their impact upon prime farmland and examine carefully whether alternative locations with less productive land, are available.

Second, there are immense problems associated with the effort to bring more land under cultivation and ecological threats posed by such world-wide simplification of complex ecosystems. It is courageous that increasingly more scientists and international organizations are becoming aware of the problems associated with the effort to increase food production to feed the millions of people added to the world population each year. A Working Conference (Willett, 1976) evaluated land as one of the 12 top-ranked research need areas to provide food. Their concluding remarks are in line with many arguments presented in this paper:

"Although the world presently is not short of potentially arable land, there are serious regional shortages. Also, land not now being cultivated is less productive, and poses serious development difficulties. Other aspects of this need area include the preserving of prime land, retaining the productivity of poorer land, developing classification systems based on land use potential, and other problems of public policy and technological development... Most important problems:

- Develop plans for retaining lands are agricultural or open space with emphasis on proper compensation for present owners,
- Develop reduced-tillage practices that are economically feasible for use with a wide range of soil, climate, and crop conditions,
- Evaluate the impact of wind and water erosion on long-term soil productivity and crop yields in relation to environmental quality".

If then all the obstacles mentioned earlier and maybe several others have to be overcome before additional land is brought under cultivation, shall we be pessimistic about the possibility of increasing food production from presently uncultivate land? Since 1978 Wagner warned us to treat any area of the world not already used in agriculture as not capable of doing so. Of course under new research and new technology some of these marginal lands may yet become productive. But we cannot tacitly assume as Wagner pointed out "that presently unproductive land is simply waiting for our touch to be brought into production".

It is strongly believed that the expansion of the cultivated area will not bring substantial increases in food supplies considering the record of the past two decades. Instead, it seems cheaper and easier to expand the food supply by intensifying cultivation on the existing cropland than by bringing new land under cultivation.

Thus, before expanding the arable land it is wiser to preserve the productivity and the size of the presently farmed area against the various factors that reduce its capacity every year. If we want to keep the price of food at reasonable levels in the near future, we have got to stop further losses of valuable land. While short-term conservation can be achieved by various policy measures, a long-term solution will come through changes in our culture. The problems mentioned earlier stem from our culture that praises growth at the expense of nature and finally mankind's own longevity on earth.

In 1968, Japan produced a simple nation-wide zoning plan that puts all land into one of three categories: agricultural, industrial, or other. Several European countries have established less effective national land-use guidelines (Arms, 1990).

United Nations and other international organizations should encourage and provide technical assistance to national governments in adding land losses in their statistical system. In addition, technical assistance should be expanded to provide national governments with policy measures necessary to preserve the size and productivity of presently farmed area. According to the chairman of CGIAR, national policy makers are now becoming more sensitive to the consequences of damage to the resource base of agriculture and are willing to consider information on the subject.

Control over population must urgently become more effective. Anthony Bailey once remarked that "the basic problem is that God stopped making land some time ago, but is still making people".

Agriculture is facing a schizophrenic situation. On one land, there is a great pressure to increase food production to feed the millions of people added to world population each year. On the other hand, the environmental movement puts pressure for a less intensive agriculture that may slow production. In addition, the resource base of agriculture is undermined by short sighted land-use policies. Global warming and the thinning of the earth's ozone layer will ahve a drastic effect on future agricultural productivity (CGIAR, 1991).

The world's farmland is a finite and vulnerable resource, an irreplaceable commodity that must be respected and preserved for mankind's longevity on earth. ●

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