A REVIEW OF THE ENVIRONMENTAL IMPACTS OF AGRICULTURE IN THE DEVELOPING WORLD: LESSONS FOR SOUTH AFRICA

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This article reviews the existing work on environmental degradation resulting from agricultural practices in the developing world, and presents the empirical facts and figures thereon. This is followed by the identification and analysis of the underlying factors, causes and effects of the agricultural environmental degradation in these regions. The "subsistence effects" which arise from poverty and the changing face of subsistence farming; the "green revolution effects" which arise from the adoption of green revolution technology, and the "externality effects" which arise from the consumption of common proprty are identified as some of the main underlying factors that determine the environmental impacts of agriculture in developing areas. The above factors, the macrosocial and microsocial factors that determine the adoption of conservation practices, and the short- and long-term implications of government policies in the developing countries are deemed some of the most important considerations for environmental policy analysis and decision-making at national and international levels. Environmental policies directed at the developing regions of South Africa are then suggested, based on the said considerations.

1. Introduction

In a world concerned with key global environmental issues such as the greenhouse effect and the changing global climate, the depleted ozone layer and the effects of ultraviolet rays on human and other lives and the contamination resulting from nuclear radiations and toxic wastes, the environmental impact of the rural populace of the developing world seem to be of little relative significance. This view is considered simplistic in view of the facts and figures presented here. While the environmental impact of manufacturers and commercial farmers in the Northern hemisphere cannot be underrated, the survival of the human race and the ecological integrity of the biosphere we live in will soon depend on how the degrading impact of the impoverished masses of humanity in the Southern hemisphere can be controlled (Lopez, 1992b; World Bank Annual Report, 1989:34).

This article attempts to provide a review of the nature of the environmental degradation caused by specifically agriculture in developing areas. It will identify and examine the "subsistence effects", the "green revolution effects" and the "externality effects" of this degradation. The three effects interact, leading to a vicious circle of poverty and environmental degradation that is perpetuated and aggravated with time (Lopez, 1992b). The causes of environmental degradation in the developing world will be shown to originate from either the "green revolution effects" or the "subsistence effects" of degradation. The identification, differentiation and analysis of the three factors are shown to be critical for environmental management and policy-making for developing areas.

The above factors, the macrosocial and microsocial factors that determine the adoption of conservation practices, and the short- and long-term implications of government policies in the developing countries are some of the most important considerations for environmental policy analysis and decision-making at national and international levels. Environmental policies directed at the developing regions of South Africa will be proposed.

The developed North is aware of their own contribution to the current environmental degradation and there have been signs of willingness to assist the developing South not to repeat the same mistakes but to develop in a manner that will conserve vital environmental public goods for global use. Examples are the proposed $1.5 billion Global Environmental Facility (World Bank Annual Report, 1991:61) and the new fund created to help developing countries change their technology to one based on chlorine-free compounds. This fund will total $240 million for the first 3 years (World Bank Annual Report, 1990:37). For the sake of their own survival and that of future generations, the South cannot expect the North to cleanup the global pollution alone. The South needs to realise the extent of their own contribution to global pollution and the extent to which they can assist its control. Development policies will have to introduce principles of sustainable development at both macro- and micro-economic levels (Goodland, 1993).

2. The 'subsistence effects' of environmental impact

The environmental impact of agriculture in the developing world can be shown to originate from two agricultural, but also socio-economic sources, i.e., the subsistence and the green revolution sources. Their impact on the environment is revealed in the "subsistence effects" and the "green revolution effects". These can be identified and separated from each other because they cause different forms of environmental damage. While the "green revolution effects" arise only after the adoption of green revolution technology (modern agricultural technology), the "subsistence effects" result from traditional subsistence farming practices.

The "subsistence effects" arise in rural areas of the developing world when population growth and, often, macroeconomic policies (e.g., high taxation of agricultural exports) impoverish the rural population. Poverty and the resultant economic pressures lead to the breakdown of traditional institutional structures that govern the exploitation of natural resources. Until recently, these institutional structures had created location specific subsistence farming systems that cooperated with nature and the broader ecological systems, in such a way that there was an efficient and sustainable use of resources. "The collapse of traditional systems leads to a vicious circle of environmental degradation and further impoverishment" (Lopez, 1992b). Rural communities have always been poor by urban standards, but they had sufficient means to satisfy their basic needs while ensuring the maintenance of their environment. Institutional collapse and over-exploitation of natural resources rapidly leads them to desperate poverty, such that they are unable to satisfy even their most basic needs.

The collapse of traditional systems may however be traced to the existence of the "dinosaur effect" inherent in the adaptation of traditional systems to change. These systems and institutions were like the dinosaurs, they could not adapt fast enough. Traditional farming practices in most places were outdated technology which could not adapt to the demands for expansion in output and agricultural productivity.

In their review of about 30 case studies that considers the relationship between development and the environment in Asia, Africa and Latin America, Kates and Haarmann (1992) concluded that the key source of rural environmental degradation is the disruption of the traditional institutions of the poor, which until recently had permitted on efficient and sustainable use of resources that left environmental capital intact. A determination of the causes of institutional collapse is an important step in the diagnosis of rural environmental problems. Studies in Latin American in particular, but also Asia, report displacement and loss of entitlement of resources originating in factors external to the communities. Similar studies in Sub-Saharan Africa emphasize internal factors.

In South Africa the Group Areas Act and the subsequent displacement of rural dwellers to marginal lands (Deneinger & Binswanger, 1992) is an external factor that preceded the internal factor of population growth.
Large scale agriculture, export-oriented forestry operations, and major public infrastructure projects are repeatedly mentioned among the external factors. Often these factors operate together. For example, when a rural land intensive project is authorised by the government, rural communities are displaced to marginal upland or similar ecologically sensitive or unstable lands, the forest lands evacuated are then allocated for large scale livestock or crop farming (eg oil palm), or forestry operations, requiring roads, irrigation and other public infrastructure projects. The large-scale farms and logging operations expose the sensitive soil to erosion, cause the destruction of biomass, loss of biodiversity; and sometimes the accompanying burning contributes to the greenhouse effect. The displaced rural population rapidly degrades the marginal lands into which they have been pushed with the inevitable result of poverty and food insecurity. Tragedies of this nature have been reported by Stonich (1989) for Southern Honduras, Browder (1988) for areas in Brazil, and Anderson (1987) for the lowlands of the Philippines.

Implicit in this phenomenon is the prevalence of hysteresis in environmental degradation. As was the case in Latin America, a temporary price boom for commercial agricultural products, created by government policies (aimed at export drive) and complementary public investment in infrastructure leads to a drastic reallocation of land use, to deforestation and biomass loss and to the collapse of traditional peasant practices due to the loss of their entitlement to environmental resources. When the temporary boom is over the disrupted institutions and other conditions in the rural community do not revert to their original state. Instead a second round of degradation of rural marginal areas commences as a result of the rural population that lose their formal employment in the agricultural project (López, 1992b). This happens because the subsistent farmers that were turned into farm labourers do not get their land back. They have no alternative but to farm the marginal lands reallocated to them for their subsistence.

Population expansion has been identified as the main internal factor leading to the collapse of traditional systems and institutions in Africa. For example, López (1992a) and López and Niklitschek (1991) have reported how population density in Côte d' Ivoire villages increased the pressure on village leaders to allow greater use of forest areas and fallow lands for cultivation. Accompanying population expansion is the problem of land fragmentation, as the same stock of farm land is transferred from one generation to an expanded next generation. At the same time, as the population increases and new value systems are introduced, traditional village hierarchies tend to weaken.

In southern Africa, the main factors leading to the collapse of traditional institutions could be found in the household economics concept and the racial reallocation of land. La-Anyane (1985) reports that during pre-colonial times the ownership and claim to land in Eastern and Southern Africa, like in other parts of Africa, was communal. This also implies that existing traditional institutions ensured that land and other environmental assets were exploited with efficiency and sustainability. However during the colonial era, with the introduction of legal title to land, vast areas of land were declared crown lands and much of the land was distributed to white settlers (as in South Africa, Zimbabwe and Kenya (Deneinger & Binswanger, 1992)). The poorer lands were assigned to the local people. Cultivation of such marginal lands, which were previously avoided by the locals, sometimes under high population density, led to rapid environmental degradation, stemming mainly from over-grazing (Rau, 1985).

The change in the composition of the rural population caused by wage employment in the mines and on the large commercial farms (in South Africa, Zimbabwe and Zambia), as well as the pressure on some arable lands while other portions of land lie unused due to village squabbles over such lands (e.g., in KwaZulu - Lyne & Nieuwoudt, 1991). Rural-urban migration leaves the aged, women and children on the land who could neither produce enough food nor instill the required discipline over the use of common grazing lands (Low, 1984; Deininger and Binswanger, 1992). Lyne & Nieuwoudt (1991) identified the reason for the idle arable lands to be the fear of loss of user-rights which discouraged renting by migrant workers who have access to land. This fear makes transaction cost greater than rental value. The solution may be institutional changes to create a rental land market. They also found that stocking rates on common grazing land is determined not only by the pasture's physical carrying capacity but also by the private cost (Pc) of keeping cattle on the common and the perceived value of keeping cattle (Py). Herd size increases when Py increased relative to Pc.

The other aspect of significance is the existence of externalities in the farmers' resource allocation decisions. The farmers do not fully consider the entire social (or community) value of the environmental resources. This lack of consideration seems to worsen as pressure from population expansion increases. López (1992) shows that farmers in western Côte d'Ivoire internalise less than 30% of the community value of the biomass and forest resources because the local financial value of these resources is quite different from their social value. This leads to excessive cultivation and fallow periods that are too short, with the consequent loss of income for the villages of the order of 20 -24%.

Internal factors related to population expansion have been reported extensively in parts of Africa and Asia. Metz (1991) has documented the interaction between population growth and deforestation in Nepal. Campbell (1981) has provided evidence for the importance of population pressure for degradation in semiarid areas of Kenya. Jolly (1989) has considered environmental destruction and deforestation caused purely by the activities of smallholder farmers in Madagascar.

On the other hand, Garcia-Barrios and Garcia-Barrios (1990) studying evidence in Mexico, and Collins (1987) in Puno, Peru, conclude that a major source of environmental degradation and agricultural productivity loss is insufficient rather than excessive population growth. They argued that resource conservation practices in highland areas, such as those they analyzed, are highly labour intensive. The phenomenon of under population and environmental degradation seems to be common in the highlands of Latin America where rural-urban migration is intensive. In Southern Africa, similar causes of environmental degradation may be found in highland regions (eg, Lesotho) as well as lowland regions (eg, Lebowa) due to the same rural-urban migration(Aihoon, personal communication,1994).
The subsistence effects of environmental impact characteristically lead to resource depletion and not environmental pollution. The main causes of this depletion are soil degradation and erosion, desertification, deforestation, over-grazing and shifting cultivation.

2.1 Soil degradation and erosion

Soil degradation and erosion is not caused solely by subsistence farming, it is also caused by commercial farming. In the developing world, however, it results from the combined effects of subsistence farming and the green revolution. In most parts of Africa, commercial farming is not prevalent,leaving subsistence farming as the main agricultural source of soil degradation and erosion(Aihoon, personal communication,1992).

Soil degradation and erosion usually begins with the removal of the vegetation cover, loss of soil fertility and impaired soil structure. Soil erosion in turn further reduces soil fertility by selectively removing the smallest and lightest particles,thereby reducing the proportion of soil colloids and increasing that of the large, inert particles of sand. A vicious circle is therefore created: the fertile topsoil is gradually removed, leaving the far less fertile subsoil exposed; because the latter is relatively compact, water infiltration into it is slow and limited; tillage becomes more difficult and less efficient; biological activities in the soil are slowed down, as a result of impaired soil structure and deficiencies of available nutrients.

The main factors influencing soil erosion are the slope of the land, the amount of rainfall or wind velocity, the vegetation cover and human activity (Arnon, 1980). The effect of slopes, amount of rainfall and vegetation cover on the rate of soil loss is illustrated by Table 1 below, which covers parts of Franco-phone West Africa.

Much arable land which was previously under cultivation has been abandoned in many developing countries owing to soil erosion. The severity of erosion in South America has earned it the nickname of the "vanishing continent". Benham and Holley (1960) estimate that a quarter of the total land under cultivation (past and present) has lost its topsoil through erosion. A survey of soil erosion in Chile, on 1 200,000 ha showed that only 12.6% was not affected, while 40% has been badly damaged (Pawley, 1963).

An FAO study of erosion and salinization carried out in Africa north of the equator indicate that 36% of the soils in this part of the continent have been affected by some degree of water erosion, 17% by wind erosion and 8% by salinization.

Holeman (1968), estimated the level of water erosion in Africa, measured the suspended sediment loads in some of the major rivers of the continent. He estimated the annual rate of sediment production in Africa as a whole to be about 180 tonnes per km^2, which is about half of what has been estimated for South America. Estimating the suspended sediment loads for some of the major rivers in Africa, he found it to be high in the Madjerdah (mouth, Tunisia) and the Cheliff(mouth, Algeria), ie 705 and 153 tons per km2
respectively; and relatively low in the Niger and the Congo, ie 5 and 18 tons per km^2 respectively.

Napier (1991), reports that soil erosion in mountainous areas of the People's Republic of China has reached crisis proportions (cf Howard, 1981; Li and Li, 1990; Luo and Han, 1990).Soil erosion on some of the farm lands in northwestern China exceeds 337 tons per ha (Lee 1984), and sediment loads in the Yellow River which drains much of northwestern China is estimated to be in excess of 30 tons per ha per year. The sediment load in the Yellow River is often so high that it is characterised as "liquid soil". Pearce *et al.*,(1990) report that soil erosion in Nepal far exceeds replacement levels. Loss of forest cover and cultivation of land resources for agricultural purposes are the major contributors to soil loss(Napier, 1991). Blaikie and Brookfield (1987a) had also attributed the loss of soil loss in Nepal to agriculture and land-slides. Similarly, serious soil loss has been reported in Indonesia (Blaikie and Brookfield, 1987b; Potter, 1987; Cochrane and Huszer, 1988; Fagi and Mackie, 1988; Pearce et al., 1990; Siebert and Belsky, 1990); and the adverse effects of soil erosion have been documented in Thailand(Ruangpanit, 1985; Harper and El-Swaify, 1988; Carpenter and Harper, 1989).

The effects of water erosion include reduced permeability and water retention in the newly exposed soil, and increased run-off, which leads ultimately to floods, changes in the depth of river beds, and erosion of the banks of rivers and streams. The cutting of gullies lowers the water table in the surrounding area, so that dry periods have a more deleterious effect on vegetation. Soil particles carried in the run-off water brings problems of siltation and loss of depth to water reservoirs, navigable rivers and ports (Arnon, 1980; Bowonder, 1986).

2.2 Burning

Burning has always been part of traditional farming, with slashing and burning as an important method of land clearing in shifting cultivation. Burning of bush and grass in savannas and steppes may also occur spontaneously by lightning or accident. In traditional farming, burning clears the land of vegetation for planting and the ash returns plant nutrients to the soil. For the pastoralist, fire is a means of removing impalatable vegetation, preventing brush encroachment over the pasture, and reducing parasites and the vectors of disease. Hunters of the Savannah country in Africa also use bush burning to drive their quarry (Worthington, 1972).

Table 1: Amount of soil loss in different areas in West Africa.

Country	Slope (%)	Mean early rainfall[a] (mm)	Soil losses (tonnes/ha) under:		
			Forest	Cropping	Base soil
Upper Volta	0.5	850	0.1	0.6-8.0	10-20
Senegal	1-2	1300	0.2	7.3	21.3
Ivory Coast	4.0	1200	0.1-0.2	0.1-26.0	18-30
Ivory Coast	7.0	2100	0.03	0.1-90.0	108-170

[a]Means over 15 years of study
Source: Arnon I. (1980)

Burning during shifting cultivation was not harmful as long as the fallow period was sufficiently long to allow the original forest vegetation to recover. Burning in shifting cultivation became harmful only when population pressures shortened the fallow period beyond the critical limit. Fire therefore has been a contributing factor to the change over from forest to brush, and from brush to grass. Burning thus is one of the major factors contributing to deforestation, desertification and soil erosion. It destroys the surface cover of vegetation and of organic matter, baring the soil surface to the effects of rain, wind, trampling by stock and game, and thereby reducing its resistance to erosion and breakdown in structure. Useful trees such as oil palms are damaged and a gradual build-up of fire tolerant, low productive species occurs (Lagemann, 1977).

The sudden removal by fire of the protective cover of vegetation in general and of forest in particular, may have considerable effect on watersheds by increasing erosion and water run-off (Glendening *et al*, 1961). The overland run-off and stream flow increases that result from burning of surface vegetation reduces underground water levels drastically, because it reduces infiltration which becomes insufficient to charge the aquifer. As a result, the flow from springs is reduced or ceases entirely, and the water level of the aquifer is lowered. Shallow wells may dry up completely (Pereira, 1973).

It is estimated that in the minor fire season from August to October 1979 and the major fire season from December 1979 to April 1980 in Kenya almost 4000 ha of plantations and natural forests, and more than 19 000 ha of grassland and bush were burned. This caused over US $300 000 direct loss from fire damage and a further US $20,000 from the suppression of growth. In 1968, seasonal fires removed 80 million tonnes of air-dry matter from the dry Savanna range resources in Sudan from which it may be estimated that about 16 million ha were burned (FAO, 1986:63).

2.3 Shifting cultivation

Shifting cultivation is a traditional farming system during which the land is cleared of vegetation, cropped for a few years and then abandoned when the soil fertility declines, and the farmer shifts his farming activity to a previously uncultivated land or a fallow land. The farmer may return to the abandoned piece of land only after a fallow period of 8-12 years in tropical rain forest, and after a period of 15 years or more in drier areas. It is a relatively safe method for conserving soil, vegetation and fauna, while providing subsistence to the population, as long as the population density remains below a critical figure (Wilde & Mcloughlin, 1976).

At higher population densities the natural cycle of regeneration is broken, soil degradation and erosion set in rapidly, yields fall, and the community often suffers from severe food shortages. According to Wilde and Mcloughlin (1976), an average population of 20 per km^2 may be compatible with maintaining yield levels on typical lateritic soils by using the traditional bush-fallow in the forest zone. The critical density may be extended to 40-50 per km^2 with ample and well-distributed rainfall as well as fertile soils. On the other hand, where rainfall is scant and soils are poor, the critical density will be reduced to about 10-15 per km^2. The system of shifting cultivation becomes self-destructive once the critical population density is exceeded.

Current rapid population growth in most parts of Africa, especially the humid tropics, has led to a shortening of the fallow period to 3-5 years. At the same time the number of crop species planted in a yearly cycle has generally been decreased.

Table 2 illustrates how productivity declines during the cropping period of shifting cultivation in different parts of Africa. The declines reflect climatic and soil conditions and the length of the fallow period (resulting from population pressure), and are bound to increase as the fallow period is shortened.

2.4 Deforestation

Pressure from population expansion and development projects in the developing world has led to the destruction of both closed and open forests all over the world. The FAO (1978) distinguishes between two types of forest: closed forest, where tree crowns cover more than 20% of the ground, and which has a more or less typical forest environment, and open forest, which represents all other areas carrying some type of wood vegetation, but which do not have a true forest environment.

Besides their direct economic value, i.e. the supply of wood, game, wild fruits, berries and herbal medicine, forests play other crucial roles: they protect the soil against degradation and erosion, restore soil fertility during shifting cultivation, ensure a continuous flow of clean water, reduce the danger of flooding, provide protection from desiccating winds or excessive temperatures, protect watersheds, and help to maintain the integrity of existing climate.

Large increases in recent years in the destruction of forests has resulted in problems of soil erosion, flood damage, silting and landslides in various parts of the world. The FAO (1978) reports that in the Azuero peninsula of Panama, out of a total mountainous forest area of 215,000 ha 42% were cleared within 18 years. In northern Thailand, 58% of the area of nearly 40,000 km^2 of forest was cleared in 56 years. In the Ivory Coast two-thirds of the 15 million hectares of the forest that existed at the beginning of the century is now lost. In Mindanao (the Philippines), one million ha of forest were cleared between 1960 and 1971.

Table 2: Decline in productivity under shifting cultivation in Africa

Country	Cropping period	Fallow	Decline during cropping period
	------- Year	--------	%
Benin	2-3	3-10	25-60
Congo	2-5	2-10	20-50
Niger	5-6	5	50-60
Uganda	1-2	0-10	30-50

Source: Braun, 1974.

The FAO (1981) estimates that closed broad-leaved forests were cleared at the rate of about 1.3 million ha per annum between 1976 and 1980. More than half of the recent and prospective clearance of closed broad-leaved forest is in West Africa, mainly in Ivory Coast and Nigeria. Other areas with serious deforestation include Burundi, South Western Cameroon, South East Guinea, Madagascar, Rwanda and lower Zaire. In the more sparsely-populated parts of Central Africa, the pressure to clear land for agriculture is less severe, although the present state of deforestation is already alarming in the Kasai and Shaba areas of Zaire. In east and central Africa the situation is particularly serious in areas of heavy population density, like those around lake Malawi, in the Copperbelt of Zambia, and in Western Mozambique. In Southern Africa, deforestation is likely to be limited to populated areas, and to represent a small proportion of the existing area.

One of the major soil degrading processes in tropical areas that follows the removal of the forest cover is "laterization". It occurs when laterite (or plinthite) soils are exposed to the alternate pounding by heavy rainfall and drying under the tropical sun, become hard and compacted and are lost to cultivation. Sanchez and Buol (1975), however claim that the extent of area prone to this damage has been exaggerated.

2.5 Desertification

Desertification, or the intensification or extension of desert conditions, leads to reduced biological productivity, with consequent reduction in plant biomass, in the land's carrying capacity for livestock, in crop yields, and in human well being. It is not confined to the fringes of deserts, but also applies to all areas that for various reasons (such as overgrazing, the onset of salinity or alkalinity or the cultivation of marginal areas) lose their protective cover of vegetation and assume the characteristic of a desert (FAO, 1986:64).

The hazard of desertification is great in even the sub-humid zone, but in the arid and semi-arid zones, as much as 95% of the total land-area is exposed to the risk of desertification (Arnon, 1980). Desert encroachment is expanding at an alarming rate in the Sahelian belt of Africa, from the Sudan to Niger.

The desertification hazard is classified as very high, high or moderate, according to the rapidity with which desertification is likely to occur if present conditions do not change. Arnon(1980) estimates that the existing area of extreme desert in Africa covers 6.2 million ha, or 20% of the land area. Some 1.7 million ha (6%) are classified as having a very high degree of desertification hazard, 4.9 million ha (16%) a high degree, and 3.7 million ha (12%) a moderate degree. A very high degree of desertification hazard covering extensive areas is uncommon. The hazard is usually limited to bands of up to 20km wide around oases. Table 3 shows the extent of present and future desertification around the world, and the estimated degree of hazard.

It is estimated that in the Sudan alone, the desert has encroached, within the last 15-20 years, over land used areas in a belt of no less than 150km width (Kassas, 1972). The situation is equally bleak in India and elsewhere in central Asia. In Southern Africa, sub-tropical rainforest has been devastated and replaced by desert and semi-desert vegetation (Arnon, 1980).

The process of desertification has been re-constructed by Bryson (1972) for the area in India currently covered by the Rajputana desert, an area once occupied by a highly developed culture with an agricultural base - the Indian civilization. The desertification process he describes is basically a man-made phenomenon. Over-population in the dry regions leads to overstocking in areas that are inherently fragile ecosystems. If range management is ignored in such areas, the result is the destruction of plant cover, large-scale erosion, and finally, in many cases, desertification. The process is usually accelerated by the incidence of a series of more than usual dry years, such as recur periodically in the dry regions.

In sub-humid and mountain areas, the main elements in the desertification process are over-exploitation of the tree and shrub areas, uncontrolled cultivation on watersheds and steep slopes, unwise tillage practices, inadequate drainage in irrigation schemes, unregulated burning for land clearing, uncontrolled bush fires, improper water management, the lack of soil and water conservation measures, the concentration of livestock around watering points, the inability of landholders to respond flexibly to drought, and the absence of integrated land-use planning.

2.6 Over-grazing

Domestic animals, especially in the developing countries, depend on natural pastures or range-land, which account for nearly one quarter of the world's land-area (FAO, 1978). Forest lands or woodlands are also frequently used for browsing or grazing, and areas in the arid regions are also used for nomadic grazing.

Most of the lands used for grazing are unsuitable for arable cropping, either because rainfall is insufficient or because of waterlogging, being too steep, shallow or stony. For these reasons the productivity of natural pastures varies from 1/5 - 1/3 ha per animal unit on well managed and fertile pastures in temperate zones to 50-60 ha per animal unit in arid areas (Arnon, 1980). In humid regions pastures conserve soil fertility and may even improve it (especially if they contain leguminous species). Nutrients and humus accumulate under the sward, conditions are favourable for biological activity, a good soil structure is preserved and the vegetative cover prevents erosion.

Table 3: Areas of existing desert (in thousands of km^2) and of those liable to desertification.

Continent	Existing extreme desert	Degree of desertification hazards[a]				Share of land area %
		Very high	High	Moderate	Total	
Africa	6178	1725	4911	3741	16555	55
North and Central America	33	163	1313	2854	4363	19
South America	200	414	1261	1602	3478	20
Asia	1581	790	7253	5608	15232	34
Australia	-	308	1722	3712	5742	75
Europe	-	49	-	190	238	2
Total	7992	3449	16460	17707	45608	(35)

[a] The rapidity with which desertification is likely to take place if existing conditions do not change.
Source: Arnon I. (1980)

In the drier regions, the ecological balance is extremely fragile and is easily upset by overgrazing which progressively leads to a reduction in the carrying capacity of land, followed by the baring of the land to erosion, and subsequently desertification.

Arnon (1980) reports that between 1955 and 1976 cattle numbers in the developing countries increased by 34% and sheep and goats by 32%, which is one of the reasons why over-grazing is a worsening problem.

3. The 'Green Revolution effects' of environmental impact

The dramatic increase in food production in Asia and South America over the last 30 years or so has been termed the "Green revolution". The technologies that made this revolution possible include the introduction of high yielding varieties (HYV), fertilizers, pesticides, mechanization and mono-cropping - together termed the "Green Revolution Technology". In spite of this technology the Revolution would not have been possible without a number of administrative, socio-economic and physical measures which facilitated the extension and adoption of these technologies.

While the green revolution technology is already an integral part of the agricultural systems of developing countries in Asia and South America, this cannot be said for all countries in Africa. In Africa, agriculture is still traditional and subsistence oriented in most countries, with commercial farming playing a lesser role. However, there is not a single country in Africa where the green revolution technology has not been adopted to some degree already by some smallholder farmers as well as commercial farmers; and the proposition to expand its adoption is not only tempting but is the current pre-occupation of most research and extension establishments. In Africa, future demand for food is increasing rapidly, present food production *per capita* is decreasing rather than increasing, the amount of under- or unutilized land available for expansion of agricultural production is limited, and the land presently utilized is intrinsically not very fertile and losing its fertility rapidly to a wide range of degradation processes such as soil erosion and desertification (CEQ, 1980). For these reasons and others of economic importance, it is not possible to dissuade developing countries in Africa that have not adopted the technology extensively not to do so, despite the inherent disadvantages.

The environmental impacts of the green revolution can be classified into two types of problems: resource depletion and pollution. The most predominant of these problems in developing countries include: loss of genetic resources; increased pest hazards; pesticide and fertilizer pollution; phosphorus , fossil fuel, water and soil depletion; spread of water-borne diseases and salinization. These unique environmental problems introduced into developing countries and arising from smallholder as well as commercial agriculture are what will be termed the "green revolution effects".

3.1 Loss of genetic resources

The introduction of high yielding hybrid varieties in developing countries has had a serious but previously unnoticed negative impact on agriculture, namely the disappearance of many traditional crop varieties. It is the plant breeders, whose work in the first place caused the disappearance, that first recognised the loss of genetic potential (in the traditional crop varieties) which is needed for further breeding of pest and other environmental hazard resistant varieties.

The versatility and sustainability of traditional subsistence farming was dependent on this variety in crops for location specific adaptation often necessary in agriculture, and various authors have reported the existence of large numbers of varieties of different crops in different parts of Africa and the developing world before the introduction of modern agricultural technology (e.g. Rau, 1985; Fox, 1987)). Fox (1987) reports that there were about 8,000 varieties of rice grown in Java traditionally, but in 1975 60% of the irrigated rice was represented by a mere 4 varieties, and in 1981, one variety, namely IR36, covered 77% of the rice growing in the east of the island.

The disappearance of traditional varieties and the diversity they offer arose from the practice of mono-culture that is part of the green revolution package. Monoculture also provides vast breeding grounds for specific pests which would otherwise be checked by other pest-resistant crops/varieties in their direct neighbourhood. Alagh (1988) reports that this has enhanced certain pest problems in India.

3.2 Pesticide use

"Present-day pesticides fall into three primary groups: The organochlorine or chlorinated hydrocarbons, the organic phosphates and the carbamates" (Stoevener and Shulstad, 1975). Pesticides may also be classified broadly into insecticides, fungicides, nematicides, herbicides and rodenticides, with the most serious and widespread environmental problems caused by insecticides (Wurster, 1972).

Insecticides can be divided into very stable (persistent) compounds and non-persistent insecticides. The stable compounds are mainly the organochlorides (eg DDT, Aldrin, Dieldrin and Toxaphene); and the non-persistent ones are mainly organophosphates (e.g. Parathion, TEPP and Malathion) and cabamates which rapidly break down into non-toxic compounds.

The use of pesticides in farming impacts on the environment through pollution, the problem of resurgence and the creation of resistant strains in pests. Pollution occurs because much more pesticides are applied than are needed to combat a given pest. The excess pesticides find their way into the soil, the underground water tables and later into streams, rivers and oceans. Pesticide residues also accumulate in the fatty tissues of plants and animals. Concentrations of pesticides usually increase down the food chain, eventually leading to lethal doses in humans, predator birds and other animals. In developing countries the problem of pollution from insecticides is made worse by the fact that it is handled by people who are not trained in their safe use. Alagh (1988) reports that 70% of the deaths caused by pesticides come from the developing world which uses only 21% of the pesticides sold in the world.

Pesticides have also been found to destroy the blue-green algae in rice fields, which reduces the productivity of these fields. Similarly, the persistence of pesticides in the soil has been associated with the destruction of soil microbes, which disturbs the precarious equilibrium of microbial life, and subsequently soil fertility (Audus, 1964).

The second major problem associated with pesticide use is "resurgence". Fox (1987) has discussed the impact of the resurgence of Brown Plant Hopper in Java on rice production caused by the killing off of the natural enemies of this originally minor pest. Resurgence of pests occurs when the environment is over simplified, thus a number of balancing mechanisms are destroyed, and previously small problems take on large proportions.

The development of resistant pest strains is another major problem that calls for action to ensure the proper use of pesticides. Resistant strains make it necessary to have expensive continuous research work to develop new pesticides on a continuous basis, and the new strains created by improper application of pesticides are usually more difficult to eradicate.

The increased use of insecticides like DDT, Dieldrin and Endosulfan in Africa has given rise to concern about their possible effects on non-target organisms. Studies in Botswana, Kenya, Nigeria and Zambia to determine the side effects of insecticides (mainly Dieldrin) used for tsetse control link the applications of Dieldrin with a high level of deaths in many wild animal species: insects, birds, fish and certain mammals. The residue levels of Dieldrin in the livers of animals found dead in an area studied in Nigeria ranged from 22 parts per million (net weight) in the Tantalus monkey, 23 in the black fly catcher, 41 in the Gambian sun squirrel, to 60 in the brown babbler (Koeman, 1978).

The intentional use of these chemicals by African rural dwellers in fishing, though not wide-spread, is a real problem which if not controlled through education and alleviation of poverty, can drastically worsen the pollution problem. The direct and indirect contamination of water by pesticides may kill fish, reduce fish productivity, and give rise to high concentrations of undesirable chemicals in edible fish tissues. In East Africa, the pesticide contamination of in-land fishery resources has recently been reported from Burundi, Kenya, Sudan, Tanzania and Zambia (Alabaster, 1980).

Food and feed contamination by pesticides is also a major problem reported in many parts of Africa. In Tanzania 36 people died between July 1969 and July 1970 as a result of eating food contaminated by insecticides (FAO, 1986). Deaths of livestock from eating feed contaminated by insecticides have been reported in Zambia (Bryden, 1971).

3.3 Fertilizer use

The green revolution effects of the environmental impact of fertilizers are due to its production and its application to the soil. The production of fertilizers contributes to the depletion of the world stock of fossil fuels (for the manufacture of nitrogen fertilizers), and the limited fossil supplies of phosphates.

The excess application of fertilizers also pollutes the ground water table, rivers and oceans. Excess amounts of nitrates are believed to be a health hazard, especially for infants. Excess amounts of nitrates and phosphates in lakes, rivers and oceans cause eutrophication (i.e. accumulation of algae resulting in the suffocation of animal life) (Biot, 1990). Losses of nitrogen to the air (nitric oxide and nitrogen dioxide) are believed to contribute to both acid rain and the depletion of the ozone layer (Arnon, 1980), which could increase the incidence of skin cancer (Crosson & Frederick, 1977). The evidence for the effect of atmospheric nitrogenous gases on the ozone layer, though, is only circumstantial (Biot, 1990).

Though the consumption of fertilizer in Africa rose by three quarters between 1969/71 and 1979, it is still very low when compared to other regions of the world. The average consumption (excluding South Africa) of only 11,3 kg of plant nutrient per ha of arable land and permanent crops in 1971 compares with 37,4 kg in South Africa, 61,5 kg in Asia and 228,7 kg in Europe. The highest levels of fertilizer use in Africa were in the sugar-producing islands of Reunion (287.8 kg per ha), Mauritius (252.0 kg) and in Egypt (212.0 kg) followed a long way behind by Zimbabwe with 48.5 kg per ha. In Rwanda, fertilizer consumption is estimated as only 0.3 kg per ha (FAO, 1986).

In 1989 only 3.7 million metric tons of fertilizer (NPK) was used in all of Africa, or less than 3 per cent of the fertilizer used worldwide. Fertilizer is almost totally restricted to cash crops, such as tobacco, cotton, tea and groundnuts. In a technical and economic assessment of fertilizer usage in West Africa (Zalla *et al*, 1977) reported that fertilizer use averages less than 2 kg of nutrients per ha in West Africa (cited by Eicher and Baker, 1992). Fertilizer pollution may not be a major problem in Africa yet, but its importance in South America and Asia can not be overrated, even when considering amounts used by only smallholder farmers.

3.4 Irrigation

Irrigation is an important part of the green revolution "package" in developing countries. The spread of irrigation in the dryer regions of the developing world is yielding short-term benefits in the form of increased productivity. However, the environmental impact of irrigation, as knowledge accumulates, has been found to be so detrimental that the long-term benefits of the technology is being questioned.

The construction of dams and the creation of large reservoirs have caused an increase in water-borne diseases such as Schistosomiasis, Bilharziosis and Malaria in developing countries. Schistosomiasis, a debilitating intestinal and urinary disease caused by the larvae of a blood fluke, is estimated to afflict 250 million people, and surpasses malaria as the worlds' most prevalent infections disease (Brown, 1977).

The creation of reservoirs may inundate valuable agricultural and forest land and displace rural population. The displaced population may be relocated to marginal or sensitive agricultural lands which may be subsequently degraded by agricultural activities and the consumption of fuel wood.

When reservoirs are located in arid regions where evaporation is usually very high, Stamp (1961) estimates that the evaporation loss could be as high as 125 cm annually; and as much as three-quarters of the water stored may be lost by evaporation (Dixey, 1966), the remaining water becoming increasingly saline. For the enlarged Aswan reservoir, the loss by evaporation has been estimated as equivalent to 10% of the annual flow of the Nile (Addison, 1961).

The siltation of reservoirs, caused mainly by soil erosion in the regions where these are located costs in terms of lost hydro electric benefits or the reduction of the reservoirs' life expectancy. The life expectancy of the $600 million Mangla reservoir in Pakistan, originally estimated as 100 years, has been reduced by half because of an increase of the rate of sedimentation resulting from the clearing of sleep slopes of the watershed for farming and from overgrazing (Brown, 1977). The Ksob dam in Algeria was rendered completely unusable within 10 years, well before the project could pay off its high construction costs (Dumont, 1966). Experience in South Africa has shown that reservoirs can be filled up with sediment within a dozen years; and in Levant and the Sinai, relatively smaller reservoirs have filled up in even shorter periods (Arnon, 1980).

The deposition of sediment in reservoirs robs lowlands of potential increases in soil fertility. The inability of the sediment to reach river deltas and to counteract wave erosion from the sea can lead to the destruction of coastal lands, as is reported to have occurred because of the construction of the Aswan dam (Arnon, 1980).

Fishing in coastal estuaries is also affected by the inability of the waters to receive these sediments. Highly productive estuaries and coastal waters lose their productivity. In the case of the Nile the production dropped from 18,000 tonnes in 1965 to 500 in 1968 (Dorst, 1972).

Kovda (1977) also reports that the construction of highland dams can cause a rise and infiltration of subsoil water streams, which can extend hundreds of kilometres up-and down-stream of man-made lakes, causing a rise in the level of ground water. If the rise is stabilized beyond a critical level of 1.5- 2 m, alkalinization and salinization may result. Also, extensive erosion and landsliding may occur along the banks of reservoirs, causing the loss of agricultural land.

El Gabaly (1977) reports that the area of salt-affected and waterlogged soils amounts to 50% of the irrigated area in Iraq, 23% in Pakistan, 80% in Punjab (Pakistan), 50% of the Euphrates Valley in Syria, 30% in Egypt and over 15% in Iran. And in Brazil at least 50% of the irrigated area in the north-eastern part of the country is affected by salinity and waterlogging, lowering yields in some of the affected areas below pre-irrigation levels (Echholm, 1976). Arnon (1980) concludes: "Small wonder, then that many of the civilizations that were based on irrigation ended in disaster, and that large-scale failures are not exceptional even in the twentieth century".

Two basic approaches to ground-water utilization have emerged - (a) the concept of "safe yields" which is based on the rule that annual ground-water harvests should not exceed the limit where it will cause undesirable effects like sea-water intrusion, land subsidence, increased pumping requirements, long-term depletion, etc and (b) the concept of "mining" ground-water, in which case harvests exceeds annual re-charge, sometimes considerably (Arnon, 1980).

Planned overdraft of ground-water utilization is required in the initial stages of development in order to sustain agricultural development, during the period of construction of dams, reservoirs and bore-holes. Assuming that this planning can be done in developing countries, the involvement of smallholder farmers in the implementation of such schemes will be difficult because of their insufficient knowledge in the management of water resources.

3.5 Mechanisation

The pressures that exist on smallholder agriculture to adopt the green revolution technology, which invariable includes mechanization is so real that we expect the level of mechanization to increase among smallholders everywhere. Nevertheless, the level of mechanization in certain parts of the developing world is quite high due to the prevalence of commercial farming, e.g., Latin America, Zimbabwe, Kenya, Cote d'Ivoire and South Africa. (Lopez 1992b).

In Africa mechanization using large tractors is already part of the farming systems found on resettlement and block farming schemes. A discussion of the environmental impact of mechanization here should therefore assist present and future decision making with regard to the direction of technological innovation in developing countries.

Agricultural machinery for tillage and post-harvest processing uses vast amounts of fossil fuels whose reserves are steadily declining. The burning of fossil fuels also causes substantial pollution problems. Sulphur emissions contained in the fumes of the internal combustion engines of tractors and other forms of farm machinery will contribute to the creation of acid rain problems even in the developing world, unless development plans aim at avoiding it. The CO_2 production from these machines also contributes to the green-house effect, global warming and the negative modification of the local and global climate (Biot, 1990).

The compaction of soil by agricultural machinery in Africa and other parts of the developing world is already well known. This problem is serious in areas where the soil is heavy clay in texture. When machinery tills the soil in dry conditions, heavy clay soils are also pulverised, contributing to dust pollution and the destruction of the soil structure, which aggravates the erosion problem.

4. Essential factors for environmental policy analysis and their implications for South Africa

There is great concern in both the developed and the developing world about what the global ecological situation will be if the extent of environmental degradation that has taken place in the industrialised countries is duplicated in the developing world. It is feared that such a process would induce radical changes in the world's ecosystem, with significant cost in terms of human lives, public health and other investments in the industrialized countries (López, 1992b). But this fear should not be a preserve of the industrialized countries alone, for similar loss of human life and property is bound to occur in the developing world as well. This is why a globally concerted effort is required in seeking long-term solutions to environmental problems. National and international effort in this direction will have to consider the following factors that are essential for environmental policy analysis aimed at smallholder agriculture.

4.1 The degradation linkages between "Subsistence effects" and "Green revolution effects"

The separation of the "subsistence effects" of smallholder agriculture from its "green revolution effects" is necessary for environmental policy analysis. While the "subsistence effects" are already widespread in most developing countries, the "green revolution effects" are less widespread. The latter effects will become a major problem only if agricultural development, in an effort to alleviate poverty and to achieve economic growth, ignores the "green revolution effects". This will happen in Africa as it already has in South America if the expansion of commercial agriculture displaces rural smallholder farmers. The "subsistence effects" and the "green revolution effects" may also reinforce each other in the degradation of the environment if the extension of green revolution technology to smallholders does not inculcate steps to mitigate the latter effects.

4.2 Subsistence effects versus externality effects as the source of degradation

While the subsistence trap brought on by poverty is confined to the developing world, externalities arising from the consumption of common property environmental goods are not. The issue is whether the observed environmental degradation in developing countries is a result of the subsistence trap brought on by extreme poverty, or due to lack of internalization of externalities by smallholders in their use of environmental goods.

The most disturbing forms of pollution are those of the atmosphere, water bodies and nature reserves, i.e. properties with "public good" characteristics. This suggests that excessive environmental degradation may be also associated with Hardins' "tragedy of the commons".

The analysis of the "subsistence effects" and the "green revolution effects" above indicates that environmental degradation in the developing world is also due to the use of common property which creates externalities that cannot be internalised; which may be termed the "externality effects" of the environmental impact. The ability to distinguish and separate the "externality effects" of environmental degradation from the "subsistence effects" will be essential in the choice of policy measures for the control of environmental degradation. This is demonstrated by López's (1992b) empirical evidence from western Côte d' Ivoire where the use of price incentives caused greater deforestation and increased biomass degradation, as the farmers responded by increasing their area of cultivation. Here, satisfaction of the farmer's subsistence needs through an increase in incomes did not lead to a decrease in the consumption of the common property (i.e., decreased deforestation or environmental degradation). Instead, the opposite occurs. Thus, the evidence from Côte d' Ivoire is not consistent with the subsistence explanation of the cause of deforestation and biomass degradation. Therefore an externality explanation of the cause of forest degradation in this case is more plausible. It is clear that in Côte d' Ivoire, stopping the forest destruction will take measures that directly discourages farmers from expanding their area of cultivation into forest areas, such as introducing intensive cultivation methods that probably depend on organic manure.

In South Africa the problem of overgrazing has been studied extensively, as one stemming from the externalities that exist in the use of common grazing, most authors suggesting privatization as a solution for localities where this is feasible (eg, Lyne & Nieuwoudt,1990,1991; Anim & Lyne, 1992). However, the contribution of poverty and the "subsistent effects" to the problem has not been isolated. This, if done, should give a fuller understanding of the problem. The broader view taken by Vink and van Zyl(1990) is a step in the right direction, and an empirical study will be most beneficial. Anim & Lyne (1992) provide empirical proof from Peddie coastal area of the Ciskei that private access to grazing land results in better veld quality, increased sales and commercial livestock production. While an improvement in veld quality will directly improve soil erosion, increased sales and commercial livestock production will indirectly contribute to a reduction in soil degradation if it reduces poverty and improves the living standards of the smallholder. Doran *et al.* (1977) argue that herd sizes decreased after the Kikuyu obtained individual ownership rights to agricultural land because land replaced cattle as the desired symbol and store of wealth.

4.3 The short and long-term implications of policies

It is also important that environmental policies in developing countries take cognisance of the fact that the environmental impact of smallholder agriculture, like other production activities, is cumulative. The fact that environmental pollution is not a major problem in developing countries now does not mean that it will always be so, if policies are not designed today to ensure that the future will be pollution-free. The deforestation, and the pesticide pollution which is already a problem in the developing world can grow to undesirable proportions in the long term.

The irreversibility of certain types of environmental impact should be a major consideration in the adoption of policy measures, in development planning and project implementation. The loss of biodiversity through deforestation and the destruction of entire wild-life species should be avoided by all means possible. The use of persistent chemicals like DDT in farming should be avoided at all cost because of the irreversible impact on ecosystems and the long-term implications.

An emphasis on short-term solutions to existing food production problems and other economic pressures through the uncontrolled adoption or extension of green revolution technology in the developing world should be avoided. Developing countries that have not gone far with their adoption of this "modern" technology should rather look at alternative agricultural systems that incorporate the principles of sustainable agricultural development, and therefore environmental capital conservation.

4.4. Institutional reform and the adoption of conservation practices

Napier (1991) agrees that while some soil erosion occurs naturally, it is mainly a result of human activity. Human beings make decisions about agricultural practices that will be used on the land in the context of social, economic and institutional factors which constrain their behaviour. Decisions made at the farm level significantly influence rates of erosion at the field level. He reports that in an examination of literature focused on the adoption of soil conservation practices in Asia, he identified two broad categories of variables that affect adoption decisions at the farm level. These are the macrosocial factors which refer to structural factors beyond the control of the land owner, and the microsocial factors which refer to individual and farm enterprise factors. Some of the macrosocial factors are population pressure on land resources, poverty, land tenure and national development policies, and some of the microsocial factors are the awareness of conservation practices, access to information systems, profitability of soil conservation practices, and value orientations of land operators.

The willingness and the ability of farmers in the developing world to adopt soil conservation practices is an essential tool needed by policy-makers and environmental managers for the control of soil degradation and erosion and the subsequent desertification. Seemingly good policies may be made and promulgated but their efficacy and efficiency in controlling degradation depends on the willingness and ability of farmers to receive and implement them. This is why the macrosocial and microsocial factors deserve attention from those who will shape future environmental policy, and more so by those who will have to implement them. An examination of the examples cited reveal that these factors, both the macro and micro ones can be influenced through institutional reform and policy, though their response to these reforms will vary.

Napier's findings for Asia are in line with those made for the South African homelands. While most authors agree on the need for a government-induced institutional innovation where local conditions allow it, i.e., through privatization of communal grazing land(eg, Lyne & Nieuwoudt, 1991; Anim & Lyne, 1992), others assert that privatization may not necessarily be the solution for every case. For example, Vink and van Zyl (1990) suggest an expansion of the spectrum of alternative institutional reform approaches and other instruments like the withdrawal or modification of the authority of tribal leaders if this authority is used to exploit the subjects and to prevent improvement to the common grazing land. They also considered changes as divers as the provision of alternative supply of milk to the locals if it is this need that makes them overstock. Cattle taxes or quotas have also been suggested as a means to reduce animal population density and over-grazing(eg, Lyne & Nieuwoudt, 1991). Dissemination of information regarding the future consequence of current stocking practices would constitute an important part of the overall strategy to reduce over-grazing (Napier, 1991).

4.5 Lessons for South Africa

It is time to caution against the new environmental problems that could arise with an expansion of smallholder agricultural practices, as the nation tries to implement the Reconstruction and Development Programme (RDP). Although all the various forms of degradation identified in this work operate to relative degrees in this country, they are bound to be aggravated unless environmental policy analysis, policy-making and management recognise the significance and role of the various factors identified here.

This is likely if people with little or no land conservation experience are given land without prior training. Similarly, if the new smallholder is not provided with all the services and facilities that ensure profitable farming, poverty will lead to the onset of the "subsistence effects". Some of these essential services are extension and training, credit, markets and social infrastructure. With the possible increment in livestock numbers comes an equal possibility of an expansion in the "externality effects" that exist in the use of common grazing land.

In Lebowa and other parts of the former homelands, subsistence living require the dependence of the rural dwellers on the trees and shrubs around them for fuel . High human and animal population density and the absence of other sources of fuel has led to the devastation of large tracts of previously wooded lands(Aihoon, 1994). The provision of social infrastructure like electricity or the introduction of improved wood or coal stoves might improve the current devastating trend.

Without doubt, the productivity of the new smallholders will have to be improved through the introduction of "green resolution" technology. The increased use of pesticides, fertilizers, irrigation and machinery is bound to worsen existing environmental problems. To avoid this, steps have to be taken to train the new farmers in the environmentally safe use of these inputs. There is need for research to determine if current prescribed application rates can be lowered. Research with alternative agricultural practices will have to be intensified and those systems compatible with small-scale operation will have to be introduced to these farmers and trained to operate profitably in them. Minimum tillage practices (Conway & Barbier, 1990; Stinner & Blair, 1990) will be quite useful in areas where slopes are steep and land quality is marginal. The increased use of organic fertilizers (or manure) will have to be encouraged countrywide. Commercial and emerging commercial farmers should be encouraged to learn more about organic farming practices that use less pesticides, e.g., Integrated Pest Management (IPM) (Edwards, 1990).

The "polluter pays" principle should apply to all producers, including smallholder farmers. All producers ought to take responsibility for their environmentally degrading actions. Smallholders should be made to directly contribute to reafforestation projects and land conservation projects that will correct their previous soil erosion and deforestation actions. Paying for their actions in labour or monetary terms shouls contribute to more responsibility and less degradation, and is one means of internalising the externalities. There is need for research to determine how best the "polluter pays" principle can be applied to the smallholder. The scope for market-based incentives to induce environmental protection, as compared to regulatory approaches (World Bank Annual Report, 1990:38; Baumol & Oates, 1971; Moxey & White, 1994; Kula, 1992; DoE, 1990) deserves investigation for all productive activities, including small-scale farming.

It might not be feasible for government to convert all communally owned lands into privately owned ones overnight, but the redistribution of land under the RDP might consider the externalities as one of the reasons for which private ownership should be preferred over any form of communal ownership. Private ownership of land, which will internalize some of the said externalities will be facilitated by the creation of an efficient land rental market (Lyne & Nieuwoudt, 1991). Government policy can assist institutional innovation in this direction.

There is need for research into how agricultural and environmental policies could be coordinated so that agricultural production incentives, such as subsidies do not increase environmental degradation (cf Shortle & Laughland, 1994). This could happen if in the process of making farm inputs accessible to smallholders, price subsidies encourage the excessive and inefficient combination of these inputs with other factors.

It may be necessary to avoid fragmentation of existing commercial farm land into unprofitable farm sizes for the emerging farmers, since this can lead to impoverishment and the subsequent over-exploitation of environmental resources especially under conditions of high population growth. Any such sub-divisions should leave farmland in economically viable sizes.

5. Summary and conclusion

The impact of smallholder agriculture on the environment is significant in the global picture because of the number of people involved in it, the geographical dispersion of its influence, and its potential damage to an already serious global ecological situation. Three main sources of influence when this impact is analyzed, are the "subsistence effects", which arise from poverty and the changing face of subsistence farming; the "green revolution effects" which arise from the adoption of green revolution technology and the "externality effects" which exist in the use of common property.

The "subsistence effects", combined with the "green revolution effects" of smallholder activities and commercial farming, have contributed greatly to the degradation of natural resources around the developing world. The "green revolution" effects, together, with the poverty factor of the "subsistence effects", have contributed to the level of pollution. Pollution levels in the developing areas are likely to worsen with the adoption of modern farming technology if the extension of green revolution technology to developing areas does not inculcate steps to mitigate the "green revolution effects" that accompany the technology.

Environmental policy analysis and decisions aimed at smallholder agriculture need to recognise the linkages between poverty and the "subsistence effects"; the "subsistence effects" and the "green revolution effects" and the different implications of "subsistence effects" as opposed to the "externality effects", for the choice of policy measures for the control of environmental degradation. Similarly, the long-term implications of today's policy decisions, as we seek short-term solutions to economic and food production problems, should not be ignored.

The effect of institutions and institutional reform on the macrosocial and microsocial factors that determine the extent of adoption of conservation practices is seen as a tool in the hands of environmental policy-makers for the mitigation of existing and expected environmental degradation. The linkages among, and the role of the various factors identified in environmental policy-making and environmental management is a phenomena worth further empirical study in South Africa.

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