SUSTAINABLE AGRICULTURE IN RURAL DEVELOPMENT USING LOCAL TECHNOLOGIES: THE CASE OF KENYA

© BEATRICE WEKESA MUSILA

A thesis submitted in partial fulfillment of the degree of Master of Arts in International Development Studies at Saint Mary's University.

September, 2000

Dr. Gene Barrett,
Supervisor

Dr. Henry Veltmeyer,
Reader

Dr. Liette Vasseur,
Reader

0-612-56716-8

DEDICATION

This thesis is dedicated to my children Moses, Nafula and Nekesa whose love and understanding gave me the strength to go on to complete this research.

ACKNOWLEDGEMENT

I gratefully acknowledge the incisive comments and suggestions by my supervisor, Gene Barrett, which helped to improve the quality of this paper. Without implicating, I wish to thank him for intellectual and moral support throughout the research period.

Very special thanks to my children, Nekesa, Nafula, and Moses, without whose round support and understanding this dream would not have come true. Thank you dear for your patience, encouragement, and understanding.

ABSTRACT

This paper examines the potential for local knowledge in sustainable agricultural development in developing countries with reference to Kenya. This task is accomplished by a critical evaluation of the existing relevant literature. The conceptual framework is based on the rural African understanding of sustainable livelihoods, which calls for a broader perspective between local knowledge and agricultural sustainable development.

The study aims to contribute towards an understanding of the concept of empowerment from the standpoint of rural African communities. This is achieved through a review of the mainstream approaches, which apparently have failed to provide an appropriate framework through which rural African communities can maintain a sustainable agricultural livelihood. This study draws the conclusion that agricultural practices based on local knowledge have the potential for sustainable agricultural development in the Kenyan environment if accompanied with appropriate policies, research and funding.

TABLE OF CONTENT

ACRONYMS

ADC	Agricultural Development Corporation
BIFAD	Board for International Food and Agricultural Development
CIMMYT	International Wheat and Maize Improvement Centre
CGIAR	Consultative Group on International Agricultural Research.
ICRAF	International Centre for Research in Agroforestry
CPK	Church Province of Kenya
IITA	International Institute for Tropical Agriculture
IRRI	International Rice Research Institute
KENGO	Kenya Energy and Environmental Organization
NARS	National Agricultural Research Stations
ISNAR	International Service for National Agricultural Research
KARI	Kenya Agricultural Research Institute
FAO	Food and Agricultural Organization
CAMBIA	Centre for the Application of Molecular Biology to International Agriculture

CHAPTER 1

INTRODUCTION

1. Background and Motivation for the Study

The theoretical analyses of environmental degradation and sustainable agricultural development in the third world countries have focused on poverty reduction or eradication and economic growth to the exclusion of other important considerations. Accordingly, conventional views have overlooked the limitation of natural resources that support all human activities and have instead assumed economic growth to be the central requirement of development. They argue that if economic growth was continued for an indefinite period of time it would eventually bring material and social benefits to people (Titilola and Mazur 1994). They also argue that through transfer of technology, the benefits will 'trickle down' to the lower ranks. Little reflection however is given to the impact of new technologies on farming systems, inadvertently emphasizing development practices that have ignored local knowledge systems in sustainable development (Shiva 1993, Titilola and Mazur 1994). These local knowledge systems have been regarded as part of a romantic past and an obstacle to development. As a result the potential for these traditional technologies to stabilize production, ensure natural resource conservation, and lead to long term sustainable development has been ignored.

In Kenya, conventional agricultural technologies have helped increase output of some cash crops in large scale farming communities, they have not performed equally well in food crop production, especially in small scale farming communities (World Bank. 1975). The hypothesis of this study is that conventional technologies that rely heavily on single crops and use of heavy external inputs, and of course with environmental damage. have failed to deliver productivity and sustainable agriculture because they have failed to recognize indigenous technologies and knowledge. The study seeks a new approach to facilitate sustainable agricultural development in Third World countries, in particular Kenya. The primary motivation in undertaking this study is to provide evidence of the potential of indigenous technologies to stabilize production, ensure natural resource conservation, and lead to sustainable agriculture. To serve this end relevant literature and case materials from developing countries in general and Kenya in particular will be used. The question that this thesis addresses is, what are the potentials in local knowledge systems to lead to sustainable development in agriculture in developing countries?

This thesis consists of seven chapters. In this introductory chapter I review and put into context some of the conceptual issues and development approaches central to the research question. Chapter 2 offers a critical assessment of the impact of the Green Revolution technology transfer to African countries. Chapter 3 provides an overview of the various traditional farming systems and proposes the bottom-up approach as a possible solution. which not only empowers the individual but the community at large. The question this chapter addresses is how sustainable and productive are these alternative methods of farming? The question is evaluated by assessing farming practices of various African communities such as the Kofyar of West Africa, Kikuyu of Kenya, and Chagga of Tanzania. The traditional farming practices are assessed not only in terms of maintaining the livelihoods of these communities but also in preserving the diversity of the environment. Chapter 4 presents the potential for biotechnology to overcome the weaknesses of Green Revolution and those of traditional agricultural practices based on local knowledge. The chapter also explores the benefits of biotechnology revolution especially for marginalized men and women farmers in rural African countries. Chapter 5 provides an overview of the debate on intellectual versus indigenous property rights. The discussion is based on the need for rural communities to have control over their own local resources in order to allow them to define their own terms of sustainable development depending on the basic needs of their communities. Chapter 6 provides an overview of women and agriculture. It presents case studies of actual experiences of how women equipped with knowledge based on the local environment, engage in agricultural practices that not only sustain their families but the environment as well. The second part of the chapter presents some limitations of modern agricultural technology on the health of women, and their socio-economic well being. Finally, Chapter 7 revisits the thesis question and situates it within the African rural communities.

1.2 Conceptual Issues

1.2.1 Sustainable agricultural Development

Sustainable development is "development that meets the needs of the present without compromising the ability of the future generations to meet their own needs" (The

World commission on Environment and Development 1987; 8). In the past few decades, 'sustainability' has become a buzz word invoked by development practitioners, theorists, leaders, and even agriculturalists, but few have attempted to define the concept clearly, or even shown how it may be measured. Sustainable agriculture is an umbrella term encompassing new approaches to farming (Rolling and Wagemaker 1998). It refers to farming in ways that protect the environment, conserve natural resources and reduce the potential contamination from toxic chemicals. This means the theory of sustainable agriculture includes the development of policies and practices that ensures a nation's ability to produce the food and fibre they need without degrading the natural resource while at the same time preserving the health of farmers (Rolling and Wagemaker 1998; Barnett 1995; Anthrobus 1996). From this definition, the term sustainable agriculture has come to mean different things to different people and many argue that absolute and precise definition of sustainable agriculture is impossible (Rolling and Wagemaker 1998). This thesis move beyond the rhetoric that characterize much of the sustainability debate and operationalizes the concept. Promoting and enhancing the natural resource base is seen as the precondition for sustainable productive agriculture.

The concern for sustainable development starts with the concern for future food availability. It is estimated that global population doubled from 2.5 billion in 1950 to over 5.3 billion in 1990 (Barnett et al 1995). In this respect, the sustainability of an agriculture that is environmentally benign in relation to world resource, population, and environment becomes an important issue. This means that sustainable agriculture is not only fashionable to pursue but it is inevitable. Sustainable agriculture does not mean a return to low yields that characterized the 19th century. Rather, it is concerned with the ability of agricultural systems to remain productive in the long term. It encompasses, but it is not limited to, farming systems known as low-input, organic and alternative. Rolling and Wagemakers (1998; 7) defined sustainable agriculture as the "outcome of the collective decision-making that arises from interaction among stakeholders". Stakeholders here include natural resource's users and managers. This implies the use of regenerative practices that maximize locally available resource and natural processes such as nutrient recycling and limit the use of external inputs of agro-chemicals. Defined this way, sustainable agriculture then requires that farmers become experts, instead of users, receivers, or adopters of other experts' wisdom and technologies. Farmers learn to use ecological principles to their own local situations (Roling and Wagemakers 1998). This definition is regarded as more appropriate because it is inclusive of what people understand sustainable development to mean for their given environment.

The United States Office of Technology Assessment agrees that appropriate technologies for Africa are those that conserve the natural resources, addresses farmer-identified problems (pest and weeds, low soil fertility, drought) and are environmentally and socially sustainable (Titilola and Mazur 1994). The assumption that this study makes is that African rural people have knowledge, skills and structures which their societies have effectively developed over decades and centuries in order to assert control and sustain not only their livelihoods but their environments as well. This thesis suggests that sustainable agriculture in developing countries should include efficient use of resources, diversification of crop and livestock species to enhance biological and economic stability, selection of crop and livestock varieties that are well suited to soil and climatic conditions, and utilization of local farm-generated resources as opposed to purchased inputs from distant regions (Hartfield and Karlen 1998).

1.2.2 Local Knowledge

The term "local knowledge" is a broad concept. In this thesis, it is used synonymously with 'traditional' or indigenous knowledge to differentiate the knowledge developed by a community from the international knowledge systems sometimes called western systems generated through universities and research centers. Local knowledge is understood as "the sum of experience and knowledge for a given group, which forms the basis for decision-making with regard to familiar and unfamiliar problems and challenges" (Warren and Casmen 1988; 4). This knowledge enables the holders to get the most out of their natural environment. Most of this knowledge has been passed down from generation to generation, but also individual men and women in each new generation adapt and add to this body of knowledge in a constant adjustment to changing environment. Warren and Cashman (1988) link the use of local knowledge with the development of sustainable agricultural systems. Altieri (1991) also define local knowledge as accumulated knowledge, skills, and technology of the local people derived from the direct interaction between human beings and the environment. Local knowledge systems are therefore characterized as strategic resources for decision making in societies that seek to maintain sustainable production and society's livelihood in periods of transformation. Local knowledge has been viewed as the basis for agriculture, health care, food preparation, education, and environmental conservation.

Farmers who use local knowledge engage in experimentation (e.g., peasant farmers in Zaire) to evaluate soil quality by the type of wild plants growing on it. Peasant farmers in Kenya also use local knowledge in managing post harvest losses due to pests (Goldman 1991). Titilola and Mazur (1994) address specific issues that ought to be considered in order for local knowledge systems to be useful at both cognitive and operational levels. At the former level, local knowledge systems is used to classify resources (soil, terrain, land tenure, and climatic factors) while at the latter level, local knowledge involves skillful individual, household, and community management of natural resources, technologies and labour. Similarly, there are specific types of local knowledge according to gender, age, and relation to the head of household, especially female heads of households (Rocheleau 1991). Recognition of the above mentioned dimensions of rural structures can create space for valuable contribution of local knowledge systems to sustainable agricultural production. This study focuses on specific knowledge about the environment that men and women in rural Third World countries use to increase their agricultural food production and sustain their livehoods.

1.2.3 Sustainable Livelihoods

Sustainable livelihood is viewed as an approach to sustainable development because it speaks about societal issues. It is a point of view of men and women whose livelihoods have been threatened by the overall process of development (Chambers 1989). The use of the term 'livelihoods' stands for the view that people sustain their lives in many ways that cannot be defined in terms of income. Athrobus (1996; 23) pointed out "sustainable livelihood approach emerged due to the growing frustration and skepticism among people whose hopes and believes in the global action to promote their well-being was shattered by the reluctance of governments and international institutions to confront the contradictions in the current socio-economical and political structures that perpetuate poverty, injustice, and environmental degradation".

1.2.4.1 Nineteenth and twentieth century approaches

During the 20^{th} century, economic approaches encouraged farmers to adopt an industrial production model for agriculture (Rostow 1960). Development and agricultural science were viewed as resulting from transfer of western science to the users (Chambers 1993). In developing countries, self-sufficient agriculture was seen to evolve through stages of development as advocated by Rostow (1960). This evolutionary perspective assumed that societies progressed through a set of linear stages to reach an era of modernization in which traditional cultural practices were replaced by modern industrial ones (Rostow 1960). In this conventional paradigm, innovation originates in science and is realized through the transfer of technology (TOT model). Experts advised farmers to specialize, use labour-saving innovations and intensify the use of purchased input. However, practical evidence from both the developed and developing worlds show that innovation emerges from interaction among people and collectives as they role play as sensible beings. In addition, local knowledge, business ingenuity, and farmer experimentation are as important as expert knowledge (Roling and Wagemakers 1998). Similarly, the claim of linear progress has been elusive especially in some developing countries and instead, there is evidence of lack of trust in positivist's top-down approaches that have failed to deal with conditions of high uncertainty such as the issue of global security.

A second development approach is the modern structuralism or dependency theory which rejected the idea of a universal theory and considered the automatic transfer of technology mythical arguing that self-sustaining economic growth can be achieved through models that reflect the structural characteristic of a society. Most proponents of structuralism such as Seers (1978) also rejected the neo-classical analysis which they argue had neglected the actual cost of development. Though modern structuralism stresses the importance of external and internal constraints on economic development. Its attempt to explain the relationship between development and sustainability is limited and the model is still based on the 19th century European context of equating development to economic growth. Therefore, conclusions drawn towards achieving sustainable development are thus limited. A revival of classical Marxism and the modernization theory in the eighties continued to consider capitalism as historically progressive and imperialism as the means through which techniques, culture, and institutions are transferred from western Europe to the rest of the world (Chambers 1989). Like liberal economists, classical Marxism explanation and conclusions of the relationships between development and sustainability is limited, economic growth is treated as development. However, alternative approaches to sustainable development do not promote conflict between redistribution and growth, instead they favour an anti-poverty approach that reduces inequalities rather than waiting for the 'trickle-down' effect of growth to occur. This line of thinking has continued to dominate agricultural research and extension where technology is transferred to the farmer through hierarchical technically oriented extension services where farmers are seen either as 'adopters' or 'rejecters' of technology but not as originators of technical knowledge or improved practices (Scoones and Thompson 1994).

Another approach is based on the modernization paradigm, which tends to favour centralization, regulation, and transferred standard technology from controlled to uncontrolled conditions using a top-down planning strategy. However, this approach ignores the fact that most societies in developing countries have complex and diverse livelihoods, which have sustained them over long periods of time. In agriculture, sustainability was believed to be achieved through the transfer of standardized uniform packages of practices accompanied by elaborate research that focused more on monocropping than complex diversified traditional systems (Chambers 1989). The latter approach perceives sustainability in agriculture as stretching to an infinite future so as to allow planners understand the many complex ecological systems and derive indicators for ecological sustainability, while the conventional top-down approach, sustainable development is viewed in stages, or development periods stretching from five to ten years.

1.2.4.2 Basic needs and anti-poverty approach of NGOs and UNDP

The concept of Basic Needs Approach consisted of needs related to human rights - including public participation in the process of decision-making, a descent standard of life, capital investment in socially appropriate technologies, and the creation and support of institutions that promote democratic participation. It gained popularity due the realization in the early 1970s that the benefits of economic growth and 'modernization' were not reaching the poor. The Basic Need Approach (BNA) called for a 'straight relationship between development strategy and elimination of poverty rather than waiting for the 'trickle-down' effects of growth (Hettne 1990). The World Bank also promoted basic needs approach but with more emphasis on economic aspects. The Bank called for 'redistribution with growth' (Hettne 1990; 168). In the World Bank's model, the emphasis is given to increasing the share of the poor in new income rather than in an initial redistribution of asserts followed by high growth rates. Basic human needs in this model become more of a guide for distributing income than a fully-fledged strategy for development. The Basic Needs Approach point to the idea that development and social arrangements should be judged according to how they promote the 'human good' and not in terms of wealth and gross national income (GNP). As Emmanuel Kant (UNDP 1990) observed, humanity should be treated as an end and not as a means. However, the Basic Needs Approach focuses more on the provision of goods and services - food, shelter, and clothing - than on the human choices and long term sustainability. The anti-poverty approach grew out of the Basic Needs Approach in the sense that low-income women were identified as a 'target group'. It was assumed that increasing the productivity and income of women in the lowest income houses would promote economic growth (Hettne 1990). This approach seems appealing to many people but the accuracy of promoting women as exclusive producers and managers of their income is still debatable.

1.2.4.3 Efficiency approach

Intellectual and political revival of the neo-liberal perspective in the 1980s marked the most recent approach to the issue of sustainable development and in addition to the encumbrance of structural adjustment policies (SAPs). The objective of structural adjustment is to restructure national economies by reducing the role of the state (privatization and cutbacks in social spending) and by promoting export-led growth, trade, and price liberalization. Efficiency, however, lead to trade off between distribution and growth, especially during early stages of development. Redistributive measures raise short term consumption by the poor, but at the cost of reduced investment and diminished prospect for long term growth (Brohman 1996). In fact, 'efficiency' may lead to irreversible environmental damage that may hinder future development options. The main aim of this approach is not sustainability but 'development' as defined by major donor agencies such as the World Bank and IMF. Within the efficiency paradigm, the market provides powerful tools for economic growth, but it is less powerful in assuring the sustainability of the environment and of rural livelihoods (Brohman 1996). Markets are also limited in properly rationing natural resources for which ownership claims have become difficult to enforce such as forests and fisheries. Absences of such property rights for natural resources cause markets to skew economic growth, often to the disadvantage to the quality of the environment (Dove 1996).

1.2.4.4 Indigenization of development approach

Mainstream development rhetoric has gone through various phases that have focused on economic growth, growth with equity, basic needs, and, recently, sustainable development. It has been thought that where mainstream development strategies have failed, the local knowledge and technology approach may be the latest and best strategy in the fight against hunger, poverty, and underdevelopment (Scoones and Thompson 1994). Since local knowledge has allowed its holders to exist harmoniously with nature, it has been thought of as the pivot on discussion about sustainable resource use (Moock 1992). Indigenization of development thinking calls for a new form of development based on knowledge and needs of people in the third world rather than expertise of outsiders (Chambers 1989). Such development approach rejects efforts to remold other people according to ethnocentric universal models and predefined standards. This means that learning about other people's culture, taking an interest in local knowledge and cultural practices is viewed as the basis for redefining development approaches.

The local knowledge and technology approach opens opportunities, especially to third world people who otherwise have had to conform to development blueprints drawn up elsewhere. Currently, most developing countries are experimenting with indigenous concepts and methods based on their own development experience and intellectual traditions. Many of these alternative approaches promote participation and empowerment by creating a sense of self-worth among people in the third world through rediscovering and reinterpreting local histories and cultural traditions (Chambers 1989 and Warren and Cashman 1988). This represents a shift from the preoccupation with centralized, top-down, and technically-oriented solutions of the past that have failed to alter the lives of the majority peasants to an approach that maximizes popular participation and empowerment.

It has been thought that increased use of local knowledge may make development programs more appropriate, enhance popular participation, and empowerment. This may lead to programs that start with local people and acknowledges that local people are skillful managers of their own environments. Kloppenburg (1991) argues from a social theory perspective that emphasis on technology adoption and increase in productivity in agriculture especially through Green Revolution technologies led to the appropriation of farmers' local knowledge and their implicit appreciation for an alternative agriculture based on local knowledge. To reverse the Green Revolution trends, Kloppenburg (1991) suggests that the specificity of a place within agricultural production need to be the preferred basis for sustainable production. He argues that to emphasize the nonspecific aspects of production will remove the source of knowledge from the farm and locate it among university and industrial interests where the kind of knowledge produced alters the balance of power away from producers. Farmers thus lose control of farm production because the source of information concerning productivity comes from outside the farm gate. This kind of agriculture is not sustainable because farmers are forced to forego the type of farming best suited to their local environment and adopt a farming system generated by a production model based on continuous technology adoption. Kloppenburg (1991) concludes that in order to generate a system of agricultural sustainability, it is necessary to replace agricultural science as conventionally practiced, with an alternative view founded upon farmer based knowledge. He asserts that local knowledge is the basis for constructing a successor science for sustainable agriculture.

1.3 Sustainable Livelihoods Approach (SLA).

The Sustainable Livelihoods' Approach is a response to the failure of mainstream development policies to alleviate poverty and to sustain the environment. It is an approach that advocates alternative and sustainable development based on popular and social mobilization. This approach differs from the mainstream economic approaches on the issues of sustainability because the former takes the view of groups (both men and women) that have been marginalized by development. It is concerned more with how men and women sustain their lives in different ways, ways that may not be easily measured in terms of incomes. In the mainstream development approaches we have discussed above, development is exclusively measured in terms of yields and incomes: more corn, more hogs, and more fruit as with the Green Revolution technologies. This approach made farmers believe that once their investment in land and machines is large enough, he/she forsakes the values of husbandry and assumed those of finance and technology. Therefore, the farmer's thinking is not determined by agricultural responsibility, but by financial accountability (Shiva 1991). The economy of money therefore infiltrates and subverts the economies of nature, energy and the human spirit. This challenges the growing capitalization and increasing domination of the scientific paradigm in agricultural education, research, and production; and has set the stage for debate over the issue of sustainable agriculture. Human agency in this thesis is seen as the ecological choices that people make and their relationship to the ecosystem, it is viewed as the basis for the development of a sustainable farming system. The goals of such a sustainable agriculture does not focus on the income and wealth but integrates the environmental health, economic profitability, social, and economic equity

(Bailey 1993). When development is defined in terms of economic growth, as defined in efficiency approach above, the conflict between sustainability and growth is evident. Sustainable Livelihood Approach is taken for this thesis as an approach that can lead to the satisfaction of basic needs, human development through a participatory process and agricultural sustainable development (Chambers 1989).

Chambers (1989) pointed out that any strategy for environment and development in the 21^{st} century that purports to be concerned with people and sustainability especially in agriculture, must confront the question of how these people can gain decent rural livelihoods in a manner that can be sustained. This thesis therefore seeks to argue that Sustainable Livelihood Approach is a more appropriate approach for development in the 21^{st} century for developing countries. The assumptions that I make are based on the idea that. Sustainable Livelihood Approach is a universal approach and can work both in developed and developing countries as it incorporates many cultural, social and political differences. Sustainable Livelihood Approach is well captured by the use of Human Development Index (HDI) instead of GNP to rank country development. Non-governmental Organizations (NGOs) and United Nations Development Program (UNDP) regard HDI as more appropriate because it captures all dimensions of human development other than one aspect of development as seen in the use of GNP. It is also my view that, the use of HDI by many mainstream institutions may just fit in as a blueprint model for human development as long as it tends to centralize, standardize and use planning from top-down. In addition, while NGOs and UNDP are using these human development indicators, there is no mention of what indicators can be used to measure cultural and social sustainability that is the backbone of local agricultural production. The measuring of human and social sustainability have eluded mainstream approaches to development, leading to the lack of an understanding of the rate at which this local knowledge is being lost. There is a need to measure these trends in order to take management action. Social sustainability may include moral, ethical, and spiritual sustainability. Traditional societies in developing countries depend on shared sets of values and ethical principles that define what is acceptable to them and what promotes the spirit of cooperation in the common interest. Human culture and knowledge are critical aspects in the development and sustainable use of ecological resources, yet these aspects have been undervalued and unmeasured as dimensions of development. The challenge here is to indicate how one generation knows more or less than the preceding one. Indicators for sustainable development should include multiple interrelated dimensions of development of any society, extending from indigenous subsistence to post-industrial communities, and from high-tech to non-tech environments.

Sustainable Livelihood Approach is based on the theory of collective empowerment where local communities identify problems, organize themselves to increase their social energy, create political spaces, and solve common identified problems. Sustainable Livelihood Approach is thus different from mainstream approaches, whose central concern is efficiency and economic growth. Unlike the mainstream approaches, the Sustainable Livelihood Approach recognizes that the beliefs of development professionals about sustainable development and of those poor rural people conflict. We may note here that there is need for a balance between the various paradigms, a balance between top-down, regulated and local level diversified, unregulated, flexible and long-term process (Chambers

1989). The Sustainable Livelihood Approach also recognizes that women's contributions have not been recognized by growth-led strategies.

Sustainable Livelihood Approach assumes that rural communities have a practical and transformative approach to sustainability which is illustrated through experiments done by these communities either on plant varieties or seed varieties to enable survival. The use of complexity and diversity are aspects of Sustainable Livelihood Approach. In agriculture, for example, systems are made more sustainable not by standardizing through adopting uniform packages of practices generated by normal research but by diversifying, using mixed cropping and canopies in their many forms to reduce risk (Chambers 1989). The Sustainable Livelihood Approach gives communities collective empowerment that allows them to identify problems and address them communally. Collective empowerment here does not refer to communities taking over power, rather it implies re-awakening of power in collaborative management of natural resources involving partnership between community and state agencies.

CHAPTER 2

THE GREEN REVOLUTION

Forty years ago, Norman Borlaug's[1] belief that in spite of the dreadful challenges of tropical Africa, most of the agricultural developments strategies that worked in Asia and Latin America would also work there (World bank 1990). This optimism led to 1960s and 1970s international agencies such as the World Bank to campaign for Africa's agricultural development through the introduction of modern technologies based on 'packages' of High Yielding Variety (HYV) seeds and the use of fertilizers, chemical pesticides and credit. The emphasis was particularly on delivery of such packages to large scale / low density farming usually accompanied by mechanization and irrigation. After Robert McNamara's speech in Nairobi in 1973, it was realized that technological transfer in agriculture had not trickled down to small scale farmers and that science and technology had not solved the problems of societal disparities in Sub-Sahara Africa, instead it had exacerbated them (World Bank 1990). According to the World Bank, there was need to concentrate more on small-scale farmers and rural development projects in which agricultural modernization was combined with provision of rural infrastructure (World Bank 1975). McNamara's discovery of poverty led to renewed interest in small subsistence farming with little focus on the sustainable practices that rural communities used in their approach to eradicate poverty and sustain their livelihood. By 1990, however, little had changed. This lack of progress was reflected in McNamara's speech to African Leadership Forum in Nigeria which echoed his 1973

Nairobi speech identifying almost the same problems underlying Africa's development crisis such as agricultural stagnation and stultifying poverty (World Bank, 1991).

From the World Bank's point of view the reason for agricultural stagnation is found in the nature of African traditional farming practices that use low levels of input and, as a result, lead to low food production and cause environmental degradation. This thesis argues that African traditional farming systems are appropriate to the changing environment and lead to sustainable high yields, and that rural communities have relied upon these traditional farming systems for generations to maintain their livelihoods. The introduction of new technology has therefore to incorporate these farming systems especially those that promote sustainable agriculture. In this chapter I survey the implementation of the Green Revolution in developing countries, analyzing the impact of these innovations on food production and environment in these countries.

2.1 Background on the Green Revolution.

The term Green Revolution emerged in the literature in mid 1960s. It depicted a breakthrough in agricultural technology that represented a solution to the agrarian problem of the developing countries. In technical terms it meant breeding plants that could bear more edible grain without increasing cultivated land (Hadjor1992). In order to achieve the Green Revolution technological transfer, intensive agricultural research often funded by the Consultative Group on International Agricultural Research (CGIAR) of international agricultural institute was launched. These research centres were committed to breeding plants with short tough stocks that could bear new fertilizer-sensitive hybrids as opposed to traditional crop varieties such as millet and sorghum, which are tall on the stock for reasons of natural selection (Kloppenburg 1988). Miracle rice, which had a short stem and therefore would not topple over, was promoted as a solution to the food problem of the Asian sub-continent. This dwarf variety capable of producing spectacular yields under ideal conditions, were eventually bred and they went under the name of HYVs. Some of the ideal conditions needed for their application included fertilizers, irrigation, pesticide, single monoculture crop variety, and extensive land cultivation and mechanization. With the Green Revolution launched, the idea of direct technology transfer from the west to the developing countries gained credibility. This transfer was based on the assumption that western technology was both available and universally applicable to large areas of the developing countries. It was also based on the assumption that investment in large-scale physical infrastructures (dams, ports, and highways) could boost the economy. Therefore economic benefits could be expected to trickle-down to the masses. Evidence, however, has shown that these assumptions are not valid. With the development of the "miracle seeds" came a host of new institutions established to provide the research required to further the Green Revolution through dissemination of seeds and education to people in appropriate agricultural techniques (Shiva 1989). For instance, four American geneticists and plant pathologists financed by the Rockefeller Foundation were sent to Mexico where they founded what is now International Wheat and Maize Improvement Centre (CIMMYT). As soon as these seeds were introduced in Mexico, yields began to increase, with wheat tripling and corn doubling between 1944 and 1967. Mexico, which had previously been importing its food from the USA, began to export its surpluses. With the wheat model success under its belt, the Rockefeller Foundation, in cooperation with the Ford Foundation, teamed up to repeat the same performance in Asia (Glaeser 1987). This time they tried with rice and founded the International Rice Research Institute (IRRI) in the Philippines in 1962. The Rockefeller Foundation and Ford Foundation continued to establish research centres in other regions of the third world, including the Centro International de Agriculture Tropical (CIAT) in Colombia and the International Institute for Tropical Agriculture (IITA) in Nigeria. At the initiative of Robert McNamara, the then president of the World Bank, the CGIAR was formed to finance the growing network of International Agricultural Research Centres (IARCs) (George 1981).

The release of the IR8, a high-yielding rice variety, in 1966 led to a huge commercial success in India, Pakistan, and Indonesia. In 1970, about 10 million hectares of land was planted by the IR8. The success of newly developed strains seemed to be limitless. Within three years Pakistan ceased to be dependent on the wheat import from the USA. Sri Lanka and the Philippines and some African countries achieved record harvests. India, which had just undergone a severe famine in 1967, produced enough grain within five years to support its population. For India, grain imports were no longer necessary as it had become self-reliant in wheat and rice production between 1961 and 1980 (Glaeser 1987). Not only did the new HYVs produce more grain per acre but also they could do it within a shorter growing cycle, allowing double or even triple cropping on the same land in a single year especially in the irrigated wet lands. In the space of only seven years (1965/6 to 1972/3), wheat acreage planted in the third world countries to HYVs went from 10.000 hectares to over 17 million hectares. During this period as many as 6 million more hectares were added to the total cultivated area. Pioneer Mexico, India, Pakistan, and Turkey headed the beneficiaries of Green Revolution in wheat. Smaller surfaces were planted to HYVs in Afghanistan, Nepal, and North Africa. Generally, areas with favourable climatic conditions witnessed increases in yields as high as 50 per cent (Glaeser 1987)).

Researchers' campaign to introduce "miracle seeds" in countries like Mexico was designed to bring "new hope" to people trapped in backward stagnating agriculture. As the Cardenas administration invested in scientific research, their purpose was not to modernize agriculture in imitation of the USA but to improve on traditional farming methods. However, the Rockefeller Foundation policy choices for Mexico systematically discarded research alternatives oriented towards non-irrigated subsistence sector. Instead all efforts went to the development of capital intensive technology applicable to only best endowed areas or those that could be created with massive irrigation (Glaeser 1987). This approach later received consistent criticism. The 1960s and 1970s were periods when Asian and Latin American countries experienced yield increases due to the adoption of HYVs of wheat, rice and maize. Their good performance was due to extensive use of irrigation, fertilizers, and pesticides. The Green Revolution however never gained similar momentum in Africa although some of the Green Revolution crops did take root.

2.2 Agriculture in Kenya

The evolution of modern agriculture in Kenya began in the colonial period during which cash crops such as tea, coffee, and maize were introduced for commercial purposes. In his report of 1902-3, Charles Elliot, the British Commissioner to Kenya at the time, stressed the need to set up a large-scale agricultural department that would undertake research on introduction of new crop varieties in Kenya. As a result, various parts of the country were surveyed and suitable crops recommended for each area. The Elliot Report became an important source of information for the introduction of new crops. The current distribution of major commercial crops reflects this legacy. With introduction of cash crops, land was alienated from Africans and given to colonial jurisdictions. In addition, all waste land and lands not under occupation was designated as crown land without consideration that the technology of the local people included shifting cultivation where large portions of land were laid fallow for a period of time (Clayton 1964; WOrld Bank 1975)

It was, however, the Swynnerton Plan of 1954 that set in motion what many have refereed to as the agrarian revolution in Kenya. The plan was designed to promote commercialization of African agriculture. By 1962, African cash crop production had doubled but as it is with technology transfer, there were more losers than winners (Clayton 1964). Attempts were made to modernize African cultivation systems by encouraging indigenous farmers to adopt new HYVs. The aim was to direct native production towards crops that could be exported. Research and extension campaigns were aimed at converting Africans to modern farming. Those farmers that were reluctant to adopt modern technology were described as stupid and reactionary while the receptive ones were seen as progressive.

From this colonial background, that had strong biases against subsistence agriculture and local technologies, emerged the current structure of plant breeding. Research and extension had been facilitated during the colonial period with research priorities primarily geared towards export crops grown by large-scale farms of coffee, tea, and pyrethrum. After independence in 1963, there was a shift in research priorities. The national economic development plans such as the 1974-78 identified science and technology as important inputs for Kenya's economic development. At the same time food crops and small-scale farming were identified as the highest priority of research (Ruttan 1987). The government's breeding work continue under the ministry of agriculture, with various National Agricultural Research Stations (NARS) devoted to major crops grown in the country such as maize, wheat, barley, pasture, and other exotic crops (Juma 1989).

Of all the crops, the diffusion of hybrid maize into the Kenyan economy has been described as one of country's most successful stories of agricultural development. However, by mid 1980s there was great concern on the part of government and donor agencies about the future of the agricultural system in Kenya. A rapid population increase (from 2% in the 1950s to 4% in the 1980s) was causing great concern about Kenya's capacity to meet food needs (World Bank 1990). Today studies continues to indicate that the initial increase in maize production began to fall in the early1980s and in fact the country experienced serious food shortages, forcing it to import maize, wheat, and milk products bringing into question the success of the Green Revolution technology.

2.3 Green Revolution: A Critique

According to proponents of the Green Revolution the single most important factor that limits crop yield and hinders the sustainable introduction of HYVs in Africa is the low soil fertility caused by natural soil infertility. They also attribute low crop production to the use of extractive farming practices and traditional crop varieties. To support their claim they cite examples of the traditional land-race crops such millet, sorghum, and cassava that grow tall with weak stems and stalks that cause them to lodge badly and make them vulnerable to many epidemics and insect infestations. They also point out that indigenous farming systems have seedbeds that are often poorly prepared resulting in patchy stands with poor spacing between plants. Inadequate attention is paid to weed control because in low soil fertility conditions weeds are not highly competitive with the crop plant because they too are experiencing plant nutrient deficiencies. Basing on this kind of accusation it was concluded that if such traditional methods continue there was going to be massive ecological damage (World Bank 1991).

However, the main problem that hinders sustainable adoption of HYVs in Africa may lay in the CGIAR research priorities. While rice, maize, and wheat were predominantly the Green Revolution crops, only maize is the principal staple food in some African countries. In general, African diets are based on grains such as millet and sorghum or roots and tubers such as cassava, yams, and sweet potatoes. These crops never received much attention from scientists and relevant research was therefore not part of the Green Revolution. Similarly, much of the African continent has infertile soils. For example, Kenya is largely made of arid and semi-arid regions and as a result faces severe pest and disease problems and scarce water for agriculture. In West Africa, for example, disease and pest problems have hindered the successful introduction of improved Indian sorghum and millet varieties. In addition, Africa's poor transportation and commercial infrastructure makes input not easily accessible by all farmers and harvests not to reach the market on time. Prior investments in human capital and development of training and research institutions by

Green Revolution countries of Asia and Latin America contributed to their success in agricultural research. India, for example, began to build agricultural colleges in the 1920s under the British colonial government. By the 1960s Indian policy makers and scientists had acquired extensive knowledge about the nature of problems facing agriculture in that country. In contrast, many African countries devoted little investment to training of agricultural scientists (Glaeser 1987:, Juma 1989).

Critics strongly argue that fertilizers and plant protection chemicals will never be an appropriate technology for Sub-Sahara Africa and that they pose grave environmental dangers. They point out that although the Green Revolution aimed at reducing food shortage, it failed partly because agricultural and rural development programs ignored local cultures that have evolved over centuries to enable people adopt to highly variable local environments. Environmental and social consequences of Green Revolution are far more disturbing and threaten the very existence of life on this planet. (Shiva 1991) has shown that the destruction of forests by large dams, salination and water logging of fertile lands, erosion of bio-diversity, and increasing pesticide residue are as a result of debt and mass urbanization in the case of Punjab.

The need for purchased inputs such as fertilizers and other chemicals as advanced technology was suitable only for resource privileged African farmers operating in well developed commercial agricultural sectors. Just having the seed was not enough; farmers had to be in a position to afford the conditions that make the seeds respond. In addition, these HYVs were more sensitive to drought and floods than the traditional land-races. For small-scale farmers who could not protect themselves against disease and crop failure, these new technologies placed them in a very vulnerable situation. These conditions disadvantaged the small-scale farmers in poorly rain-fed areas making the new seeds and the technology accompanying them less neutral than claimed by their proponent. Similar criticisms have been leveled at the improved use of seed-fertilizer technology of wheat revolution in India and Pakistan in mid 1960s. The Green Revolution is given as an example of the inappropriate technology that attempted to solve the problem of crop production for Third World countries through the introduction of cereals of HYVs that required massive inputs of pesticides, fertilizers, irrigation, and machinery. These new packages failed to take into account the features of subsistence agriculture, crop mixtures, diet requirements, and levels of resource used by local farmers. Poor farmers soon abandoned the new variety because of their high production costs (Glaeser 1987).

The assessments based on the experience of the wheat revolution in India, Pakistan, and Mexico indicate that new seeds show greater yield variation than the traditional seeds they displaced. The HYVs are more sensitive to drought and flood than their traditional predecessors. They are prone to water stress-inability to assimilate nutrients when not enough water is getting to the plant roots during certain stages in their growth cycle. For example, the new sorghum planted in Upper Volta is also less drought-resistant than their local cousins (Shiva 1991). The HYVs can also be vulnerable to too much water; being shorter they cannot tolerate the higher flood levels that traditional varieties can endure. Since they are sensitive to too much or too little water, they need not just irrigation but sophisticated water management. The new seed therefore require special knowledge to be used effectively. The implication of this is that the new technology is in favour of those who have access to government agricultural extension agencies and instruction literature. The new seeds are highly biased towards those who are wealthy. The hybrid corn and sorghum, for example, do not remain genetically pure year after year. To maintain high yields, new hybrid seeds must be purchased each year. This requirement gives the edge to the wealthier farmer and those closely linked to seed distributors and credit sources. Most farmers with only land to grow food for their families cannot afford to purchase hybrid seeds (Lappe 1998). As noted by Borloug (World Bank 1990), unless small-scale farmers in Africa participate in commercial agriculture, adoption of improved varieties will be stymied. These biases are subtle because the new technology puts a relative handicap on those whose asset includes traditional knowledge of the characteristics of soil and whose energies are absorbed by the labours of husbandry. It gives an advantage to those skilled in manipulating influence. According to this assessment the slow adoption of the Green Revolution is not due to the fact that farmers in Africa are locked in traditional and cultural farming practices. It is because the new technology failed to provide equal access not just to credit but to alternative decision making process where the farmers themselves become innovators and active participants in agriculture processes.

Since the Green Revolution package is dependent on high-tech high-energy strategies, small-scale farmers had no option but to use chemical fertilizers, pesticides, and irrigation in order to obtain high yields. In most cases, farmers could no longer rely on the seeds they had selected and stored themselves but gradually became dependent on seed suppliers, and thus reducing control over their own production (Soetomo 1992). Economically, however, farmers could not keep up with increased cost of production based on artificial fertilizers, pesticides, and other inputs. As a result, many farmers stopped purchasing commercial seeds and started to plant second, or third, or even forth generation hybrid seeds. Combined with problems of soil fertility, this resulted in low productivity further eroding incomes obtained from hybrid crops. In an attempt to search for alternatives to hybrid, farmers returned to local varieties and traditional farming systems.

In many third world countries crops have traditionally been bred to produce not just food for humans, but fodder for animals, and organic fertilizer for soils. Shiva (1991) notes that increasing the nitrogen uptake of plants through using artificial fertilizers upsets their carbon-nitrogen balance, causing metabolic problems to which the plants react by taking up extra water. As HYVs grow in popularity, they replace the land-races that had co-existed with their wild relatives. While land-races and wild relatives alike were plowed under, fertilizers reduced the ability of wild plants to compete. Pesticides removed many of the natural predators in the ecosystem. The use of herbicides, necessary to grow the HYVs, killed many of the wild relatives that grew as weeds (Hoyt 1988). The HYVs from international crop centers were from the beginning uniform and few in number compared to great diversity of land-races. Genetic uniformity can make a crop vulnerable to epidemics of pests and diseases. When farmers grow the same variety, pests that strike one plant can quickly spread over a large area. The dramatic dangers of genetic uniformity were evidence during Ireland's potato plight of 1845 (Juma 1989 and Shiva 1991).

The introduction of HYVs has brought about a marked change in the status of insect pests such as gall midge, brown plant-hopper, leaf-folder, and whore maggot. Most of the HYVs released so far are susceptible to pests with a crop loss of 30-100 per cent (Shiva

1991). Other aspects of the Green Revolution package have exacerbated the natural vulnerability of HYVs to pests. Large-scale monoculture provides a large and often permanent niche for pests, turning minor disease into epidemics. In addition, fertilizers have been found to lower plant resistance to pests. The result has been a massive increase in the use of pesticides, in itself creating further pest problems due to the emergence of pesticide-resistant pests and a reduction in the natural checks on pest population. The miracle seeds of the Green Revolution have thus become mechanisms for breeding new pests and creating new diseases (Shiva 1991).

In Asia, Latin America, and rain-fed regions of Africa where record successes were reported, forests were cleared to make way for the expansion of agriculture. Crop rotations have been abandoned in favour of single cropping and cropland is now used for soil depleting crops year in year out. Since the start of the Green Revolution the area under wheat, for example, has doubled and the area under rice has increased five-fold. During the same period the area under legumes has been reduced to half. The result of such agricultural intensification has been a downward spiraling of agricultural land use-from legume to wheat to wasteland (Shiva 1989). The abandonment of legumes from cropping patterns removes a major source of free nitrogen from the soil. While HYVs rapidly deplete micronutrients from the soil, increased fertilizer usage does not compensate for the overuse of the soil. A survey in Punjab indicated that half of the 8706 soil samples exhibited zinc deficiencies reducing yields of rice, wheat, and maize by up to 3.9 tones per hectare (Kang 1982). Many scientists in developed and developing countries are beginning to show interest in traditional agriculture particularly in small scale mixed cropping systems as they search for ways to remedy deficiencies in modern agriculture. Research now shows that many farming practices once regarded as primitive, unproductive are now being recognized as sophisticated and appropriate. As will be shown later, small-scale farmers have used these systems to solve problems of slope, flooding, droughts, pests, diseases, and low soil fertility. They have used these systems to increase their food production and conserve the environment.

CHAPTER 3

TRADITIONAL FARMING SYSTEMS

The Green Revolution strategy of the 1960s and 1970s assumed that successful technology transfer would eradicate social economic disparity between the developed and developing countries and between the rich and poor. However, by the 1970s it was evident that Green Revolution's trickle down approach had not materialized in most African countries as judged by the increase in the number of economically marginal households. At the same time fertile soils became exhausted and poor marginal lands were added to cultivation. which, in turn, added to environmental degradation. This chapter examines the ecological perspective in tropical agriculture by assessing alternative traditional farming systems such as the use of agro-forestry, polyculture cropping, cover cropping or mulching, use of green manure, crop rotation, and shift cultivation. These alternative approaches aim at a balanced locally adapted development strategy that takes into account long-term sustainability and the avoidance of irreversible damage to the environment (Glaeser 1987).

Traditional farming systems have recently gained recognition because they emanate from the cultural context of the people concerned, evolve in close contact with specific environmental conditions, and are based on the traditional society's intimate knowledge of their environment (Titilola and Mazur1994). A shift in attitude has taken place as many people are now abandoning the theory of unlimited growth in favour of a more balanced ecosystem. This, however, does not automatically justify the assumption that traditional systems lead to sustainable development while western methods and technologies (Green Revolution) have a negative impact on the environment. Sometimes sustainable methods can become unsustainable.

It has been estimated that about 60 per cent of the world cultivated land is still under traditional and subsistence methods (Titilola and Mazur1994). This low-input technology has benefited from centuries of cultural and biological evolution that has adapted it to local conditions. Thus, small-scale farmers in the developing countries have inherited complex farming systems that have helped them meet their subsistence needs for centuries even under adverse environmental conditions with little or without depending on mechanization. chemical fertilizers or pesticides (see Figure 1). Farmers choose practices designed to optimize productivity in the long term using locally available resources. Productivity comparisons between Green Revolution and traditional agricultural systems ignore the fact that traditional farmers consider total farming system production and not just yield of one commodity (Shiva 1993).

Ruttan (1987) contends that because resource-poor farmers cannot afford to purchase chemical fertilizers, the first steps in improved soil fertility management should be low cost technologies such as cover cropping mulching, crop rotation, minimum tillage, and agro-forestry systems. Around the Usambara mountains, for example, Glaeser (1987) found that maize and beans are planted in areas exposed to light, with sweet potatoes and local vegetables scattered among them. A multi-storeyed culture is built up that imitates the perfect original structure of the virgin forest. This technological approach prevents weed growth and pests. Permanent soil cover of organic material guarantees humus conservation. Soil erosion is also prevented. Tillage is restricted to the installation of planting-holes. At the same time cattle is kept in stables and their manure carefully collected and used for selective fertilizing for bananas (Glaeser 1987). The Kikuyus, who live along the slopes of the Aberdare Mountain, practice polyculture to sustain their densely populated region of up to 350 per square kilometer. They use terraces and fortified fodder lines to control soil erosion and use any organic material to mulch the fields. Studies indicate that in many parts of Africa the soil is so poor that it cannot even absorb the nitrogen fertilizer on which the new seeds depend (World Bank 1990). In such areas the first step is not to introduce new technologies but to use locally available technologies such as crop rotation including grass and legumes and adding organic matter to rebuilt soil structure (Lappe 1998). With the arrival of the Green Revolution in the 19th and 20th centuries in third world countries, the landscapes that were densely populated with forests were altered within two decades. Tree stands were cut, forests cleared, and polycultures replaced by modern varieties that required intensive fertilization such as coffee and tea.

The Kofyar of West Africa have successfully used traditional farming with a repertoire of techniques such as intensive ridging, intercropping, crop rotation, and green manuring that they have used to establish permanent farms and increase production. Evidence indicate that by 1983 the average Kofyar farming household had a total of 514,000 yam heaps while rich farmers had 8,000-10,000 generating an income of N 438,925 or an average of N615 per household and a total mean annual income of N 1,160 (Netting 1989). Contrary to the belief that it is only through the adoption of new crops and more productive techniques, the Kofyar's indigenous farming system is evidence that food production could possibly increase without capital intensive mechanization planned provision of seeds, fertilizers, extension services, and rural credit. Glaeser's (1987) study of the East African region indicates that the local people have managed to convert their patterns of shifting cultivation to intensive permanent agriculture. Using organic manure, they produced sufficient food supply for up to 400 people per square kilometer even on poor leached-sandy soils. Like other rural African communities, the Kofyar have an excellent working knowledge of the environment and an effective local technology. They also have low capital requirements since they rely on household and community organized labor and are not involved in land speculation. This helps them to freely experiment with crops, soils, and water while carefully intercropping millet, sorghum, yams, cowpeas, and rice. Growing sorghum after millet harvest, combining weeding and shoring up of the sorghum and providing heaps for the next years yam rotation helped them avoid working the hard soils of the dry seasons and saved time in the planting bottlenecks after the rains.

The Kofyar community used a farming system that it evolved and adapted using hand tools, traditional cultigens, and used organized labor by household and festive groups. For the Kofyar, the use of genetic diversity has provided them with security against pest, disease, and unexpected climatic conditions. Genetic diversity helps small-scale farmers maximize production in the highly variable environment in which they tend to cultivate their crops. Higher yields were obtained from employing a mixture of crops and crop varieties; each adapted to the microenvironment in which it grows, rather using one or few modern varieties. Uniform varieties may reach their potential if the environment is also uniform with high quality land, fertility, and water status. Much of this environment is achieved through the use of fertilizers and irrigation which is unavailable to small-scale farmers in developing countries especially Africa (Cooper 1992). Based on thousands of years of experience and a better knowledge of their agricultural production systems, the Kofyar have developed multiple strategies for their farming systems, almost all of which maintain genetic diversity. As Shiva (1991) notes, the high productivity of uniform and homogenous systems are a theoretically constructed category, based on taking one dimensional yield and output into account and ignoring the multi-dimensional yields of diversity-based systems of productivity. For example, in indigenous agriculture, cropping systems include a symbiotic relationship between soil, water, and farm animals and plants. However, Green Revolution agriculture replaces this integration at farm level with the integration of the inputs such as seeds and chemicals (Shiva 1993).

An agricultural strategy based on traditional cropping systems can therefore bring moderate to high levels of productivity using only local resources. Farmers grow different crops adapted to different localities, which reduces the risk of economic loss caused by undesirable environmental conditions or pest control. In drought prone areas of northern Ethiopia, for example, wheat and barley are grown in specific mixtures. The mixtures of land-race population consist of genetic lines that complement each other and are adapted to the region in which they have evolved but differ in the mechanisms they use to express traits such as drought or pest resistance (Worede and Makhib 1993). These farmers plant more than six crops together in their backyards. These crops mature at different periods making maximum use of scarce land and labour resources, minimizing weeding problems.

and maintaining soil fertility. In Ethiopia, where more than 85% of the people live as subsistence farmers, the introduction of Green Revolution strategy in which extension workers give farmers sophisticated packages of scientifically derived high yield seeds and fertilizers pesticides is problematic considering the country's extremely low average per capita income (Worede 1992). The majority of farmers cannot afford to purchase necessary chemicals even at government subsidized prices. Further more, the improved seeds are designed for uniformly stable environments such as the unvarying plains of American Midwest. By contrast, the farming areas in Ethiopia, as everywhere in Africa, are highly diverse. This makes the improved seeds very vulnerable to failure, which could result in famine for millions of Ethiopians subsistence farmers. Promoting the new seeds also endangers the rich and unique biodiversity of Ethiopia and possibly wipes out varieties of local seeds (Worede 1992).

A program called "seeds for survival" has been set up to counteract government's monocropping strategy in Ethiopia. It is putting its money into land-races that Ethiopian farmers have developed over centuries. Accordingly, within a single field of land-race wheat, more than fifteen varieties grow side by side providing more food security for the farmer; if one variety fails due to disease or pests, the others are likely to survive. "Seeds for survival approach" is to promote the productivity of land-races and preserve diversity (Worede and Makhib 1993). Similarly farmers around the developing world have attempted to develop self-reliant capacities in order to produce their own seeds. They have developed various organizations that seek to rescue and reintroduce farmers' varieties. This allows farmers to conserve local plant genetic resources and establish ways that they can participate in the generation of technology. However, after hybrid maize was introduced, farmers were given incentives such as cheap and easy credit to substitute local varieties with commercial hybrids. Ethiopia like elsewhere in Africa needs not only a distinctive Green Revolution but also a revolution that is based on locally available resources (Worede and Mukhabi 1993).

Technology transfer through the Green Revolution has had far reaching impacts on farmers' capacity to control their environment using their local technologies. In some areas, farmers may not have the knowledge of local varieties for producing their own crops (Shiva and Dankelman 1992). Instead, local varieties are confined in the minds of their parents and grandparents. Further, in regions where hybrid was heavily promoted farmers' confidence in their skills in seed multiplication is lost. However, farmers who have been subjected to the aggressive propaganda of the Green Revolution would not recover their self-confidence overnight. It may not be easy for farmers to believe that it is possible for them to develop local varieties that would perform well as those packed under the Green Revolution technologies. For example, local communities in conjunction with Non Government Organizations (NGO) such as Technology for Rural and Ecological Enrichment (TREE), began a rescue operation to save genetic resource from being lost as the government of Thailand aggressively introduced new seeds coupled with agricultural loans and extension services. After two years TREE was able to collect over 4, 000 accessions of rice and almost 3,000 of other food crops. The use of Green Revolution technologies to select seeds in various parts of the developing world cleaned out traditional cultivars that performed well under low input conditions. In central Java, for example, farmers collected 26 traditional rice cultivatars and observed their performance compared to the HYVs promoted by their government. They found that in the absence of chemical inputs, seven traditional cultivatars outperformed three HYVs. In Tegalsari village farmers found that the 37 rice cultivators stored in their community seed banks outperform the rice HYVs distributed by the government (Worede and Mukhabi 1993).

Unlike modern agriculture, agroforestry combines trees, crops or animals. By combining agriculture and forestry production, food crop production can be better achieved. The environmental as well as socioeconomic advantages of these integrated systems over monoculture agriculture include the protective function of trees in relation to soil, hydrology, and plant protection, which can be utilized to decrease the hazards of environmental degradation. It should be remembered, however, that in many agroforestry systems the components might be competitive for light, moisture, and nutrients. Therefore trade-off must be considered. In particular some religious beliefs can cause people to manage or mismanage natural resources, including forests. For example the Tzotzil of Mexico associated forests with dangerous deities, demons and supernatural forces. While other indigenous groups such as the Maasai associated forests as sacred places, to be preserved for ritual purposes (Castro 1991). However, the role of religion in preserving natural resource is beyond the scope of thesis. Studies done by Altieria (1987 and 1991) indicate that when complex structure of traditional agroecosystems are used, they minimizes crop loss to insect pest through a variety of biological mechanisms. One crop may be planted as a divisionary host, protecting other more susceptible or more economically valuable crops from serious damage (Altieri 1995). Subsistence farmers therefore can regulate pests without recourse to expensive and dangerous chemical insecticides.

Furthermore, the great diversity of crops grown simultaneously in polycultures helps to prevent the built up on the comparatively isolated plants of each species (Altieri 1995). In Africa where shifting, fallow, slash and burn are practiced, the clearing of small plots from secondary forest vegetation also permits that easy of natural pest predators from the surrounding forest. Farmers may prevent the regeneration of woodland in fallow by grazing and burning. This is important in tropical Africa where trees may harbor tsetse flies. However, valuable tree species such as *Acacia albida* used as source of animal fodder and believed to enrich the fertility of the soil around it are always left standing whether land is cultivated or left fallow (Altieria 1991).

Soil fertility is maintained through a number of strategies. The most common way of replacing lost nutrients is by the use of manure. The manure is derived from cow- dung or by compost vegetation derived from crop residues, household wastes, and leaves and other plant material collected from nearby forests (Altiera 1995). In West African rainforest farming upland rice or maize is sown first and later interplanted with cassava and plantains. Once the maize or cassava has been harvested, the cassava continues to grow for a further year and the plantains for a further two years. The advantages of intercropping are that the mix of crop plants can be chosen so that the combined leaf canopy is more efficient at intercepting light than a monocrop, and similarly the different root systems can exploit in complementary ways. Interplanting also promotes conservation of water and nutrients. It reaches its most sophisticated form in agroforestry systems. The trees not only provide organic matter to enrich the soil but also shade for the plants growing below. In addition, their canopy protects the soil from the erosive impact of rain. Inter-cropping of diverse plant species helps provide habitats for the natural enemies of insect pests as well as alternative host plants for pests. Particular agricultural practices were also associated with specific agroecological conditions, including the use of crop rotations, intercropping, winter ploughing, soil and water conservation, and organic farming (Alteria 1991). Specific technologies arise out of these practices, which when identified by farmers bring higher yields, more reliable yields, control pests, and improve soil fertility. Intercropping and crop diversification can minimize crop fluctuation and total crop failure, thereby helping to stabilize income and food supply

Table (1) in the Appendix adopted from Altieria (1995, p.118) illustrates management strategies and practices used by traditional farmers throughout the developing world. The table indicates that rural farmers using traditional farming had a reportoire of ecological knowledge, which they used without recourse to heavy input of chemical fertilizers. Farmers in Uganda manipulated timing to avoid stem borers and aphids in cereals and peas (Richard 1985). As already explained, the Kofyar, the Kikuyu, and Chagga have successfully multiple cropping systems not only to control pests but also to conserve the genetic diversity.

Seed selection and breeding methods is another way that farmers use to control weeds and the spread of pests. In Africa, they select the best sorghum heads from the field before the harvest could start. The process of plant selection was complicated basing the selection techniques on observation throughout the growing season. During this period boys are posted in the field as bird scares, keeping an eye on sorghum heads while fathers check sorghum heads for any bird-damage. Women too observe sorghum plants. looking for candidates for selection. In parts of Sudan, local community seed banks exist (Worede and Makhib 1993). The seeds are supplied on credit and experienced seed selectors are identified by the community and utilized. Experienced selectors observe the performance of the crop from germination and throughout the entire growing season. Farmers discuss the performance of the seeds as they walk and watch the fields. They also watch the fields of their neighbors and may request seeds they are interested in planting (Worede 1992). This reveals a culture where seed selection was supported by great knowledge, interest, discussion, and devotion of much time to these activities. Seeds are exchanged in local markets, where assortments of varieties adapted to different environments are available. Farmers know where to locate new supplies of seeds when traditional land-races become degraded. Where land is flat, wind and water carry pollen from one field to another. To maintain traditional land-races farmers visit other areas to acquire seeds of recognized land-races. Farmers maintain land-races, for example, of barley and elite land-races on small and isolated plots. It is important that the knowledge of farmers of sustaining the process, which produce elite land-races, is recognized. However, traditional seed conservation activities are becoming eroded by new improved seeds spread by extension systems. The farmers most affected are those in drought prone areas and those who depend on traditional methods of seed dissemination and production to ensure the supply of adaptable planting material (Worede 1992).

A good example of pest management using traditional methods is Nigeria's on farm experiments to solve the problem of *striga* (witchweed), a parasitic plant that chokes off their staple cereal crop root. The Niger producers have selected short-cycle millet that can reach sufficient maturity by the peak time of *striga* attack so that grain formation is little impaired. This approach complements another long standing indigenous strategy against *striga* in which sesame is sworn in the same seed pocket with the food grain. The sesame works as a 'trap crop' to divert the *striga* attacks. When selecting sorghum seeds farmers in Zimbabwe use agronomic descriptions such as maturity period, soil and water requirements, and tolerance of weeds, insect, pathogens, and droughts during the growing season as well as susceptibility to bird-damage (Dommen 1988). Qualities such as disease resistance and drought tolerance may be incorporated into the cultivated crop in this manner. However, the above agricultural diversity and plant breeding technologies especially as practiced by African farmers have been accused of being responsible for food crisis and a declining export production. It has been suggested instead by international organizations such as Food and Agricultural Organization and the World Bank that the Green Revolution provided the only way in which the third world could have increased food availability (Shiva 1989). This, however, undermines the fact that the breeding strategy for the Green Revolution has consciously been sacrificed for a single use with non-sustainable consumption of fertilizers and water.

Traditional land-use practices can become unsustainable when conditions change. A prime example of this is the slash and burn cultivation (also known as shifting or Sweden). This ancient practice of cutting and burning vegetation to clear space for crops also releases plant nutrients that can be taken up by those crops, and was once one of the most sustainable forms of agricultural land use. However, today, this method is considered as the major cause of forest destruction, soil degradation, and erosion. The reason behind the shift from sustainable to extremely harmful method of slash and burn is population density. Slash and burn is only sustainable under conditions of low population density, which allow for sufficiently large areas of vegetation cover to remain untouched and lie fallow for a period long enough to allow the soil to regenerate itself. Where population density creates a shortage of land, fallow periods are reduced well below 10 years and sometimes to as short as two years forcing entire areas to come under slash and burn including unsuitable sites on steep slopes (Altieria 1995). However, Wilson and Kang (1981), study in Nigeria, indicate that the use of shifting cultivation and fallowing can be sustainable if accompanied by an alley cropping system. In alley cropping, crops are planted in alleys formed by trees (2-4 m wide). The tree and shrub provide green manure over crops and shade while proved leaves are used as mulch during the fallow period to suppress weeds. Evidence from this chapter has shown that the use of diverse crops in the traditional farming system is favored over monocropping because the use of mixed cropping, agroforestry, polycultures, crop rotation is sustainable not only to the environment but allows rural people have descent livelihoods. This is because the use of polyculture for example promote diets: the use of 500 grams of maize per day and 100 grams of black beans per day will provide 2,118 calories and 68 grams of protein. Similarly, they increase income and stabilize production. Productivity is sustained when one crop in combination is damaged before maturity the other crop may compensate for the loss. They minimize risk, reduce insect, weeds, and disease and intensify production with limited resources. Because of the appropriateness of these cultural traditional approaches to agriculture, Thurston (1991) came to the conclusion that they are highly sustainable and deserve better respect than they have received from conventional views on third world agriculture. His conclusion is based on his study of cultural practices used by thousands of small-scale farmers in Third World countries. He had found out that, crop yields were sustainable over a long period of time even under stressful conditions. (See Table 2 in Appendix adopted from Thurston 1991).

CHAPTER 4

BIOTECHNOLOGY AND BIODIVERSITY

Biotechnology: The promises

As the miracle of food stability fades out, biotechnology[2] and genetic engineering are being proclaimed as chemical free solutions to the problems created by the Green Revolution. Early proponents of plant biotechnology billed it as a revolutionary technology - one that would produce miracle crops that would fix their own nitrogen from the air and resist disease. In the 1980s biotechnology proponents foresaw a bright future for agriculture where corn would thrive without added nitrogen fertilizer; cotton plants would withstand insects without added insecticides; and on the whole drought-tolerant crops that will reclaim environmentally degraded land. After ten years of laboratory and field tests the promises of plant biotechnology have proved elusive. It has taken longer and costs more than imagined (Rissler and Mellon 1996). This thesis however, is mainly concerned with biotechnology development in selective breeding of crops and how these developments can help rural farmers in third World countries develop a sustainable agricultural system.

A major study in 1988-1990 by the World Bank and the International Service for National Agricultural Research (ISNAR) concluded that there were many potential benefits from integrating modern biotechnology with conventional Green Revolution agricultural research. This could be done by focusing public sector investment on 'orphan commodities'

- crops traditionally of less interest to the industrialized countries but of great importance to the vast numbers of resource-poor producers and consumers in the developing world (FAO 1990). Several experiments point at the revolutionary potentials of biotechnology by use of biological nitrogen fixation, herbicide and pest resistant crops. In particular, genetic improvement for resistance to or tolerance of major insect pests and diseases is important because of its low-cost approach. Many have claimed that this will also lead to environmental protection because of the avoidance of application of often-polluting pesticides (Goodman 1987).

The long history of fermented foods in various parts of the world proves that biotechnology is not a recent science. Biotechnology as a rudimentary selection of plants and animals with desirable traits and breeding them under controlled conditions probably go back to the dawn of civilization. Biotechnology like any other science has historically evolved through stages. As early 700 BC biotechnology products such as traditional methods of fermentation to produce food and drinks were being used. Farmers have been using compost, waste material that is degraded by microorganisms, as fertilizers for centuries and passed the knowledge acquired during this period on to subsequent generations as part of the cultural heritage (Juma, 1989). Initially, biotechnology was largely an indoor activity, but has now begun to leave the laboratory and to enter the outside environment. After a decade of development, chemical and seed companies are beginning to commercialize the first transgenic crops (crops that have been genetically engineered to contain traits from unrelated organisms). The commercialization of transgenic crops is important to the environment because it will mean the release of many genetically engineered organisms under uncontrolled conditions. As commercialization proceeds, environmental risks, which are now considered hypothetical will become real (Rissler and Mellon 1996).

It is well documented that third world countries could benefit from biotechnology (Juma 1989; Rissler and Mellon 1996 and FAO 1990). For example, the development of varieties that use water more efficiently would enable certain marginal bioclimatic and soil regimes to become productive agro-ecosystems without recourse to costly irrigation schemes. Similarly, forest species genetically engineered for rapid growth or other quality could alleviate the fuel-wood, deforestation, and erosion problems that now characterize much of the third world (Buttel et al 1985). Plants can be produced that contain their own pesticides, generate their own fertilizers, and resist common plant diseases and lethal doses of weed killers (Mavfarlane 1990). According to this view, biotechnology application could provide opportunities to promote sustainable development. Juma (1989) points out that acquiring biotechnology for third world countries may lead to renewed growth in agriculture and industry resulting in economic benefits such as higher productivity, lower production costs, or smaller crop losses to pests and disease. However, there is little evidence that might enable governments to assess economic, social and environmental costs of this technology. Farming could benefit from the use of biotechnological agents that control insect pests and diseases affecting crops, and from the breeding of crop varieties such as those which give greater yields are adapted to local conditions. The use of tissue culture could assist the propagation of certain tropical tree species and this would be an advantage in reforestation.

Biotechnology can positively be pro-poor. It may help to create new markets, both through the breeding of new industrial, medicinal, and aromatic crops and through changes in downstream processing. Given their richness in indigenous biodiversity, several developing countries such as Brazil, China, and India, which have biotechnology capabilities, can use this biotechnology for the production of high value pharmaceutical and industrial products based on their local flora. The harmonious agroecological settings and availability of relatively cheap labour is conducive to large-scale production of new high-value crops, especially medicinal and aromatic, enabling such countries to maintain a comparative advantage. The use of biotechnological techniques for the development of biofertilizers (biological management of pests), which are scale-neutral and labour-intensive, will be particularly suitable for resource poor farmers. However, their transfer will require high-quality management, which also requires complementary changes in training and extension activities (FAO 1997).

There is however a growing concern about the control of biotechnology and the potential risks to health and environment. It is important therefore to develop international procedures to assess these risks and identify environmentally sound technology (Rodda 1993). What is questionable is the fact that biotechnology research is being paid for by profit-oriented corporations whose interests are incompatible with the demands of an ecologically-sound and socially sustainable agriculture (Kloppenburg 1989). In addition, potentially dangerous biotechnological products for which testing is forbidden in industrialized countries may be tested in developing countries where regulations governing such tests are non-existent or improperly enforced (Walgate 1990 and Shiva 1991).

The production of food crops in Africa is especially low and marked fluctuations in agricultural output are experienced (Titilola and Mazur 1994). At the same time, HYV technology for crops such as sorghum, millet and root crops is limited. As discussed above, among the constraints to agricultural production are low-use of input, low fertility of soils, climatic and weather vagaries. There are therefore great expectations that plant biotechnology has the potential of making a significant contribution towards increased crop productivity, stability and sustainability of production especially through the development of cultivars resistant to biotic and abiotic stresses, and the increased use of biofertilizers. From various meetings held in Africa during the past few years such as the Regional Symposium on Biotechnology for Development (Nairobi, Kenya, February 1992), it emerged that plant biotechnology offers enormous opportunity for agricultural growth and sustainable production with environmental protection. Reduced input costs associated with the increased adoption of disease and insect pest-resistant cultivars and biofertilizers will especially benefit small-scale African farmers. It is also believed that reduced use of pesticides will promote biodiversity, minimize health hazards and promote the marketing of fresh fruits and vegetables. The new technologies where appropriate are considered extremely cost-effective in the long run (FAO 1997). In particular, post-harvest losses in Sub-Sahara Africa recorded as high as 40% of farm produce may be altered by biotechnology research. These can be achieved by research that promotes higher quality of crops and seeds able to withstand the high humidity and temperatures of the tropics (FAO 1997).

The development of biotechnology especially in genetic engineering might be used to produce wheat, rice, and other crops that can feed themselves and fight off pests without the aid of chemical fertilizers or pesticides. Already cactus genes for drought resistance have been combined with soybean to produce high-tech hybrid crops able to withstand drought (Rissler and Mellon 996). Because of the potential benefits of biotechnology, it is hoped by many that this technology will lead to diminishing dependency on agrochemicals by poor farmers, thereby reducing their cost of production and also help ease the balance of payment's situation for developing countries. This, in turn, may enable third world governments to reallocate huge amounts of scarce resources now being used to buy costly fertilizers from abroad (Juma 1989).

Biotechnology: A Critical Approach

A revised mission statement of CGIAR (1991) reinforced the potential benefits of biotechnology and beliefs that it can be used to contribute to sustainable improvements in the productivity of agriculture and forestry in developing countries. The CGIAR's ultimate aim is to improve the nutrition and economic well being for low-income people, including women, land-less labourers, and poor producers and consumers in both in rural and urban areas. Biotechnology research hopes to contribute to self-reliance by increasing the purchasing power of the poor through lower costs and prices and through greater equity in income distribution. The Consultative Group systems achieve these objectives by identifying and transferring high priority technologies to developing countries and by establishing a standing group of experts to deal with the role of biotechnology in world agriculture (Barker and Plucknett 1991). However, from examples used in this thesis, I point out that biotechnology like the Green Revolution will not benefit the rural poor because its research is not people oriented. Similarly, biotechnology research priorities do not it strive to promote alternative and sustainable agriculture development based on multiple cropping, agroforestry, and rotation techniques (Altieria 1995). The use of these techniques enhanced and led to sustainable production systems over the centuries in many parts of the developing world. Consultative Group systems claim that biotechnology will not substitute conventional agricultural research, rather it will be used in conjunction with traditional plant breeding and other agricultural research to help provide new information and tools to solve problems. However, in this chapter I point to the contrary, that biotechology not only substitutes conventional research but undermines traditional plant breeding and the needs of the developing countries are not only lost in the total research effort, but that there is little funding made by private firms in the improvement of orphan commodities or in many technologies designed for the resource-poor farmers. Where there has been biotechnology research committed to peasants and small farmers, the research has been poorly funded or embedded with other research considered more interesting by conventional agribusiness or agri-scientific interests. An example of these is the work of the Centre for the Application of Molecular Biology to International Agriculture (CAMBIA), based in Canberra, Australia where farmers have tried to use sophisticated genetic engineering techniques to serve small scale and peasant farmers (Mugabe 1994). They develop seeds through a sexual reproduction so as to allow farmers to propagate and maintain superior cultivars. Such environmentally sound research is under funded while the US National Science Foundation, the Department of Energy and National institute of Health, continue to provide over $100 million over a ten-year period for research on commercial biotechnology (Jefferson 1993).

Biotechnology also poses challenges determined by how, when and where it finds application. In particular, the fast-paced research predominantly funded by private sector investment and use of intellectual property rights in industrialized countries are seen as evidence that the application of biotechnology will hold the key to competitiveness and comparative advantage in the field of agriculture and food. (The science of developing biotechnology does not differentiate between developing and developed countries). However, the application of such tools in the development process requires preconditions which are easily found in many developed countries, but which hardly exist in most developing countries (Mugabe 1994; Juma 1989).

In the maize sector, the control of new genetically engineered varieties rests with the world's largest transnational corporations, which they have actively researched and patented new biotechnological varieties. However, little research has been done on the ecological impacts of such crops, their potential to reinforce social and economic equalities by benefitting rich farmers and corporate interests over poor farmers (Streinbrecher 1998). Biotechnology will continue to be dominated and to respond to the needs of agribusiness industries. Instead of providing standard solution, biotechnology research could provide tailor-made answers to local problems. The only way these problems can be identified is by involving the local farmers familiar with them in the research process. For example, no drought-tolerant crop variety will have any agricultural significance without a farmer using it (Kimbrell 1998). Understanding the use of new agricultural crops implies understanding the social relations of production in a community. Plant breeders and biotechnologists need to address the following question. Whose interests are best served by plant breeding improvement? This question is important because the experience of the Green Revolution and the transfer of agricultural technologies in general have shown that neglecting social and cultural base of agricultural research can lead to social problems. These include increase in social differentiation and politics of controlling farmers' practices through supply of inputs (Kimbrell 1998).

Biotechnology and the Developing World

The level of research, development, and use of biotechnology for agriculture and forestry in developing countries is below that of industrialized countries although a few like Brazil, Mexico, India and China have gained full scientific and technological capacity in agricultural biotechnology. However, many other developing countries have inadequate funding, poor human resources and limited access to information particularly in biotechnology research. All these resources are costly and require highly trained personnel. Most developing countries are vague as to their immediate needs in agricultural biotechnology. Few have appropriate proprietary- right protection systems or mechanism to increase their access to protected techniques and products. Further, the biotechnology situation in Africa is not promising, although a number of countries have formulated biotechnology policies but most of them are still statements of intent (Mugabe 1994).

Currently organizations, such as the Rockefeller Foundation, are committed to investment and development of biotechnology research capacity in Africa. It is believed that biotechnology can be applied in Africa in phases. Tissue culture is the first phase (Mugabe

1994). This phase is hoped to provide rapid propagation of plant material and also facilitate development of organizational skills needed to operate and maintain a laboratory. The second phase will include technological tools such as markers for pests and pathogens or anther culture to shorten breeding cycles. When this stage is achieved, the last phase will include the development of a capacity to transform and regenerate plants, allowing the insertion of a particular gene construct into varieties (Pardy 1995). As already mentioned above, many African research institutes such as the Kenya Agricultural Research Institute (KARI) may be working on the second or even third phase, while in others the first phase is probably undeveloped or even others are not aware of the technology at all. For those institutes that are working on the first and second stages like in Kenya, Zimbabwe and Tanzania they are committed to full exploitation of research on Biological Nitrogen Fixation (BNF), which will help reduce expenditure on fertilizers. BNF seeks to improve crop yields in the legume host plant by using genetic engineering to improve the capacity of the bacteria (rhizobia) to fix nitrogen. The research aims include enhancing soil fertility, increasing crop production, and reducing the pollution of the ground and fresh water caused by the heavy application of fertilizers (Mugabe 1994).

KARI is pioneering the development of modern biotechnological approaches to existing programs, especially tissue culture technology for producing uniform and disease free seedlings of potato, pyrethrum and tea. Efforts are underway to develop innoculants for leguminous plants and transfer of technology to farmers. Biotechnology priorities include micro-propagation of planting materials for bananas, cassava, sweet potato, citrus and macadamia. Magabe (1994) noted that, the Kenyan consumption of fertilizers was expected to rise to over 250,000 tonnes by 1993, and so for the last fifteen years, KARI has undertaken research on BNF. Most of this research has drawn from previous efforts of the colonial agricultural research system to develop nitrogen innoculant for legumes in order to raise productivity from exotic breeds of cattle. KARI has also extended the research to cover bean inoculation. The research demonstrated that the common bean *phaseaolus Vulgaris* has the potential of fixing nitrogen up to the equivalent of 50 kg of nitrogen per hectare per year. However, the sale of inoculants to the farmers has been lower than expected, because farmers experienced income decreases due to government cut backs as part of structural adjustment policies that resulted in a 40% reduction of financial support to extension programs (Mugabe 1994). In research, organizations such as KARI, working with scientists from the Crop Science Department of the University of Nairobi and Egerton University, there is no research committed to an environmental assessment of the impacts of this new technology to Kenyan environment. Neither is there any commitment of funding towards traditional approaches such as mixed cropping, which have proved to be sustainable in the past. In addition, the social and economic viability of this technology is not being considered. What third world researchers should be aware of is that the use of tissue culture can generate variability in the laboratory, but it may increase levels of uniformity in the field. Moreover, the DNA transfer to crop improvement may also result in a greater degree of genetic uniformity among cultivars. For example, the NBF Calgene has succeeded in isolating a bacteria gene, that, when transferred to a tobacco plant and successfully, expressed confers resistance to the herbicide glyphosate (Monsantos 'Roundup'). Calgene has therefore added to variability to tobacco gene pool. If commercially incorporated this may result in increased genetic uniformity for tobacco (Streinbrecher 1996).

Threat to Biodiversity

A major problem with modern agriculture that has already been identified in the previous chapters is the loss of biodiversity, which reaches its extreme form in agricultural monocultures. In developing countries, biodiversity can be used to help the great mass of resource-poor farmers who are mainly confined to marginal lands and rain-fed areas in achieving year-round food self-sufficiency. The use of biodiversity emphasizes soil and crop protection through the integration of trees, animals, and crops (see Figure 2 in the Appendix).

Modern agricultural practices stemming from the rise of breeding industry and from the Green Revolution have caused massive genetic erosion. That is, the disappearance of many diverse populations of crops maintained by farmers and adapted to local conditions. The application of modern biotechnology may result in a wider use of genetic diversity, whether present in wild or domesticated species for benefits of future food security. However, it may also result in the further narrowing of the genetic base of our food crops because of the high costs of biotechnology and, consequently, the tendency to focus on few varieties or breeds (Rodda 1993; Shiva 1993). There is an important link between biodiversity and biotechnology. The genetic material used in biotechnology is found in abundance in the areas of great biological diversity of the tropical forests (Rodda 1993). The loss of this biological diversity is an important issue. As I will argue in chapter 5, there must be mechanisms for effective cooperation with reciprocal benefits between biotechnology rich developed countries and the gene rich developing countries to ensure preferential treatment for owners of genetic resources with regards to biotechnological manipulated resources.

One concern that has a particular global impact is the fact that engineered crops threaten the centers of diversity-areas that support populations of traditional crop varieties and their wild relatives. They are the sources of new genes that plant breeders and genetic engineers use to adapt crops to changing environmental conditions (Shiva 1991). The diversity in centers had already started disappearing at an alarming rate because farmers abandoned land-races in favour of Green Revolution cultivars (Juma 1989). In addition, habitants are destroyed as human population expands (Risller and Mellon 1996). Fowler and Mooney (1990) have extensively documented examples of indigenous strands of wheat that have virtually disappeared in India and Greece since these countries contracted and committed themselves to the Green Revolution and biotechnology. Similarly, the IUCN and WWF estimates that up to 60,000 plant species-nearly one in four of the world's total may become extinct or near extinct by the middle of the next century if the destruction of nature continues at the present rate (Hoyt 1992). From the above examples, it can rightly be said that widespread use of engineered crops exacerbates the loss of diversity by displacing wild relatives by either crops or by other populations carrying advantages transgenes. Similarly, the pressure to replace land-races with new cultivars may be intensified as the biotechnology industry markets transgenic cultivars of major and minor crops around the world. As already mentioned above the risks posed by biotechnology accelerate the already dramatic loss of the genetic basis of the world's food supply (Fowler and Mooney 1990)

The claim that biotechnology is the solution to worlds' food crisis may be but a myth. On the contrary, biotechnology may be the basis of the destruction of the genetic base on which food security especially for the Third World is based.

Engineered crops may become weeds in agricultural and non-agricultural settings. 'Weeds' in common usage are plants that happen to be in the wrong place at the right time. But a plant may be a weed in one place and a desirable plant in another place. For example, some local people use as food indigenous vegetables like *Amaranthus* and *Vigna*, which are believed to be poisonous weeds and inferior in nutritious content. For the Moru of Sudan, wild plants growing in the cultivated fields are not all weeds but many are valuable pot herbs giving much better nutrition for less labour than introduced and formally recognized vegetables (Sharland 1990). Even pests such as termites are a delicacy to the Moru who collect them each year from termite hills. Biotechnology development needs to understand the food values of local communities before destroying weeds because the needs of the crops may be put above the needs of the people (Sharland 1990). Nearly all food fibre crops such as rice, barley, sorghum, and some tree-crops have close relatives that are regarded as weeds in other parts of the world..

The case of Kudzu's introduction into the United States is instructive about the damage that can result when a non-indigenous plant finds a successful ecological niche in a new environment. Kudzu was first introduced in the United States in the late 1800s as an ornamental vine to shade the porches and courtyards of Southern homes. In the 1900s, it was promoted as a forage crop and widely planted to reduce soil erosion in the 1930s. However, Kudzu soon spread out of control and today Kudzu infests an estimated seven million acres in the Southern United States, despite repeated attempts to remove it. This does not mean that non-indigenous species are not beneficial. In fact, they are the backbone of world agriculture but the enormous damage done by many that are harmful such as fire ant, boll weevil, and purple loosestrife. They have threatened human health, disrupted ecosystems, and displaced native organisms. The United States Office of Technology Assessment agree that genetically engineered organisms are among the many kinds of non-indigenous plants pose environmental threats (Risller and Mellon(1996). To prevent and decrease the impact of weeds, the Unite States farmers, landscapers, home gardeners. resource managers and government agencies spend billions of dollars. The United States Environmental Protection Agency is estimated to have used 628 million pounds of herbicides. an amount that is unaffordable to farmers in developing countries. The possibility that genetic engineering will convert crops into weediness is debatable among scholars within genetic engineering fields. For example, Keller and Turner (1991) hold that weediness is a complex trait and converting crops that are non-weedy to weediness from transgenic crops is small. They use corn as an example of a non-weedy plant that in spite of adding transgene it would be difficult to imagine that one or two transgenes would enable corn to displace other plants in unmanaged setting (Keller and Turner 1991). Others like Rissler and Mellon (1996) point out that few crops are ecologically debilitated as corn. Surveyed situations indicate that through pollen transfer, some gene flows from non-transgenic population of wild to weedy relatives of the crop. Some of these transgenic relatives may become weeds that farmers must control. Examples include rice. corn. sorghum. and millet. Because the weeds are so similar to the crop plants. it is difficult to differentiate from crops for control purposes. There is also the risk that transgenic crops may be able to invade nonagricultural habitats (in most cases, centers of diversity-Africa, Asia and Latin America) and may be competitively superior to native species. This means that the movement of transgenes could threaten the diversity of land-races. Plants that are vital for the future world food supply and are also a source of genes that allow plant breeders to modify crops as environmental condition change. However, these complex and adverse impacts have received little attention from genetic engineers or regulators.

Pesticide Resistance

Shiva (1993) argues that when insects and weeds become resistant to herbicides, farmers use more pesticides, which flow into the ground water. Based on India's experience with monoculture in corn, Shiva points out that soil begins to wash away while at the same time pesticides kill off micro-organisms in the soil and organic additions are reduced. Because heavy mechanical equipment are used, the soil is compacted causing erosion problems. Thus farmers end up paying more for inputs that eventually degrade and destroy the environment into which they are being ploughed. The claim that biotechnology is ecologically safe and that it will launch a period of chemical-free agriculture is therefore doubtful. For example, the introduction of hybrid cotton created pest problems. Pesticide resistance resulted in epidemics of white fly boll-worm, for which the peasants in India used more toxic and expensive pesticides to eliminate and ended up incurring heavy debts and some being driven to suicide. Even when pesticides and herbicides did not kill people, they killed peoples' sources of livelihoods. An example of this destruction is that of *bathua*, an important green leafy vegetable with very high nutrition value, which grow as an associate of wheat. With intensive chemical fertilizer use of *bathua* has become a major competitor of wheat and has been declared a 'weed' and killed with herbicide and weedicide Shiva (1993). Herbicide resistance also excludes the possibility of rotational and mixed cropping, which are essential for a sustainable and ecologically balanced form of agriculture, since other crops will be destroyed by the herbicide. The US estimated a loss of US $4billion per annum due to crop loss as a result of herbicide spraying. In the case of the third world countries the destruction and loss will be far greater because of high plant diversity. In most third world countries thousands of women make their living by weaving baskets and mats with wild reeds and grasses. These women will lose their livelihood from increased use of herbicides that kills the reeds and grasses. Like the Green Revolution, biotechnology development will increase herbicide use and increase the damage to economically and ecologically useful plant species. From this illustration it can be said that strategies of genetic engineering for herbicide resistance are destroying useful species and may end up creating superweeds (Shiva 1993). In the tropics, there is an intimate relationship between weeds and crops where weedy and cultivated varieties have genetically interacted over centuries and they hybridise freely to produce new varieties. Genes for herbicide tolerance, pest-resistance and stress-tolerance that genetic engineers are striving to introduce into crop plants may be transferred to neighboring weeds as a result of naturally occurring transfer. Biotechnology may well diminish genetic diversity and increase genetic vulnerability (Kloppenburg 1988). Because of these reasons the third world countries need to reject the introduction of herbicide and pesticide resistant crops because of their health, ecological and economic impacts, including labour displacement and incresase of capital intensity of agriculture.

The basic need of biotechnology is to conserve and improve hardiness, nutritional value and yield of diverse crops used by the poor. However, dominant research has focused on gene transfer for pesticide resistance. Herbicide resistance research excludes the possibility of rotational and mixed cropping that is the basis of sustainable and ecological forms of agriculture and food security. These traditional cropping patterns have also helped in pest control. Since many of the pests are specific to particular plants, planting different crops in different seasons and different years causes large reductions in pest populations. Such cropping systems require less irrigation, which has been found to prevent the spread of the pests (Ramrasad 1998). Making plants tolerant to specific chemical herbicides has been the most common genetically engineered trait developed and tested. Trials in the United Kingdom have been done on corn, sugar beet, and cotton. The theory behind this test is that fields grown with engineered crops can be sprayed with a specific herbicide at any stage in the growing season without killing the crop plants. Weeds have been known to take away nutrients from food crops. Further, economic costs are incurred when weeds are harvested along with the crop reducing the quality of crop seed. Regular spraying allows weeds in and around genetically engineered crops to develop resistance to the herbicide the crop is tolerant of. As weeds become resistant higher and higher doses of herbicides would need to be used, leaving large amounts of chemical residue on the crops. In the long run the engineered crop may in itself become a weed. The effects of chemical herbicides are well documented. They reduce soil fertility, pollute water, deplete earthworms and beneficial microbes, and have varying short and long term effects on human health (Briggs1992). Japanese researchers among agricultural workers have found out that they had symptoms of acute poisoning following ingestion of Round-up. People suffered from gastrointestinal pain, vomiting, swelling of the lung, pneumonia, clouding of consciousness, eye or skin irritation, diarrhea, fever, weakness and destruction of red blood cells (Cox 1991). Therefore, the chemical has detrimental environmental effects. In addition glyphosate-containing products have been found to kill beneficial insects such as parasitoid wasps, lacewings and ladybugs. Round-up has also shown to affect earthworms and beneficial fungi, to inhibit nitrogen fixation, and to increase the susceptibility of crop plants to disease (Cox 1991). Still it is not clear how the widespread use of these crops will impact beneficial species. French researchers for example, have found out that some varieties of transgenic Canola can harm bees, a farm's most effective pollinator, by destroying their natural ability to recognize flower. However, herbicide resistance already exists in nature through the existence of natural resistance in the soils that selective herbicides are made applicable (Shiva 1991). Wheat, for example, has natural resistance to Glean (a *sulfonylurea* compound produced by Du Pont) When Monsanto develops soybean varieties, these only increases the sale of Round-up to benefit the agribusiness. Biotechnology is also committed to drought tolerant varieties.

Widespread application of herbicide-resistance such as Monsanto's Round-up Ready Soya and Cotton are introduced to third world farming systems may lead to increased use of agri-chemicals, thus increasing environmental problems. This will also destroy the biodiversity that is the sustenance and livelihood base of rural women because what

Monsato considers weeds are food, fodder and medicine for third world women. For example, in India women use over 150 different species of plants for vegetables, fodder and healthcare. The spread of Round-up crops will destroy this diversity and the value it provides to farmers. It will also undermine the soil conservation function of cover crops and mixed crops, thus leading to accelerated soil erosion (Streinbrecher 1996). Profits from herbicide resistance are considerable. For example, Glyphote (Monsato's Roundup) is non-selective and kills anything green – weeds, as well as crops - and its use in agriculture is therefore limited. Herbicide resistance makes sense for capital but society at large may not enjoy the net benefit. Extensive use of herbicides resistance is not without cost. many people think that intensive use of these chemicals will only deepen environmental and human health problems with which such herbicides has been associated. Corporate proponents of biotechnology insist that this new technology will genetically displace various capital-intensive inputs such as use chemical fertilizers and pesticides (Streinbrecher 1998)

Pesticide-tolerant and Pest-Resistant Crops

Research is underway to develop soybean varieties resistant to the herbicide atrazine. Similarly, the genetic engineering firm, Calgene, has isolated a gene. which confers resistance to 'Round-up' a herbicide developed by Monsato. The company is hoping to develop 'Round-up' resistance plants, specifically cotton. Chemical companies who also sell the herbicide develop most of these crops. The impact of this herbicide-engineered tolerance on the use of chemicals in agriculture is debatable; however, developments of herbicide-resistant crops will simple prolong agriculture's dependence on hazardous chemical inputs. For example, the development of bromoxynil-tolerant cotton (the first herbicide-tolerant crop approved for commercial use) was found to be highly toxic to fish. Therefore, anything that would encourage the use of bromoxynil raises important questions about potential adverse impacts. The important issue to be addressed is whether the new herbicide for which tolerance is sought will be less hazardous than those they replace and whether their application will reduce herbicide use. By offering crops tolerant to herbicides, chemical companies can expand the market for their products. The major developers of herbicide-tolerant plants are companies with herbicides to sell (Rissler and Mellon 1996). Besides herbicide tolerance, genetic engineering is also focused on the production of crops that resist pests such as insects, viruses and fungi. Pest and fungal resistance are desirable because pesticides used to combat insects and fungi can be highly toxic. To combat insects, the added genes produce insect toxins and, in the case of viruses, the new gene products interfere with viral multiplication. Keeping pests at bay is said to increase yields and in some cases, allow reduction in the application of pesticides, thereby lowering costs and reducing environmental damage. However, the first round of insect resistant crops, for example, employ the same toxic genes to produce insect resistant in crops including corn, rice, tobacco and many others. Where resistance to toxin occurs, genetically engineered plants will lose their effectiveness, and conventional farmers may resort to chemicals once more (Streinbrecher 1996).

Private Appropriation of Biotechnology

Ownership of recent progress in biotechnology has become a great asset as the Green Revolution was in the 1970s. The new science has undoubtedly penetrated the third world markets and replaced import commodities. Some fear that the corporations could even threaten governments with starvation or simply wage a biological war against them in order to secure the best conditions for the furtherance of their interests. Patrick Mooney, a 1985 Alternative Nobel Peace Prize winner and of Seeds of the Earth (1977) issued this alert, "where the Green Revolution, which began in the 1960s, affected only three crops - rice, wheat and maize. Genetics revolution may involve any combination of plants, animals or microorganisms. Whereas 830 scientists worked with the Green Revolution, research in genetics is presently a 5,000-man project. In the Green Revolution, high-yielding varieties with homogeneous characteristics boosted production through the use of heavy doses of fertilizers, herbicides, and abundant irrigation. Seed producers and chemical companies made substantial profits" (Kloppenburg 1991).

Goodman et al (1987) observed that the seed is the delivery system of the new plant biotechnology. Those that acquire propriety rights to improved plant variety hold the key to the control of agricultural production process and domination of the market for agro-industrial inputs. These profit opportunities have attracted major chemical, oil pharmaceutical and food processing firms to take over commercial seed companies and genetic research firms on a large scale. As Tewels (1983) observed 'new plant science companies will find it advantageous to participate in the ultimate marketing of science via the seed.' In short, plant biotechnology can be used to strengthen rather than weaken the dependence of food and food fibre production on traditional synthetic agri-chemicals. As with the Green Revolution, new crop varieties will form the nucleus of 'technological packages', but genetically engineered seeds now will ensure that farmers are bound far more closely to proprietary agri-chemicals. There is also concern that private plant breeding activities are displacing public agencies as the dominant force in varietal development and advanced biotechnological research because of commercial concerns. The large corporations such as Mosanto and Hoechst, using their Research and Development experience, vast resources and flexible funding methods, now dominate commercial biotechnology and the direction of fundamental research.

Economic Effect: Biotechnology and Imports

One major negative impact of biotechnology is the speeding up of the process within industrialized countries of the substitution of products or high-value components of specific products originally derived from the produce of developing countries. This depresses the limited opportunity for exports by the latter. Several significant agricultural exports of developing countries are already threatened. In particular, recent biotechnology strengthens the action of substitution by loosening the food industry's dependence on agriculture as conventionally defined (Juma 1989). The range of raw materials converted into food products will radically restructure certain food products. The impact of high fructose corn syrups (HFCS) on the sugar industry. For example, a number of developing countries are now using biotechnology to produce a natural vanilla flavour in the laboratory - a process which could eliminate the need for traditional cultivation of the vanilla bean.

This could result in the loss of over US$50 million in annual export earnings for Madagascar, jeopardizing the livelihood of some 70 000 small farmers (Juma 1989). Tissue culture production of certain components could displace their field production. For example, biotechnology laboratories in Europe, the United States and Japan are standardizing techniques to substitute cocoa butter with cheaper vegetable oil, which could adversely affect the cocoa economy in several developing countries in Africa. Other high-value products such as pharmaceuticals, fragrances, flavourings and spices are also targets of biotechnology research (Goodman et al 1987).

Biotechnology advances in agricultural processing have also led to the separation of plants from their specific characteristic, resulting in the substitution of one product for another. A good example is the increasing competition between sugar and starch producers. The production of alternative sweeteners has adversely affected the sugar industries in the developing countries, threatening the livelihood of an estimated eight to ten million people in the developing countries by loss of traditional sugar markets and a drop to world sugar prices. The development of High Fructose Corn Syrup (HFCS) from maize in the United States resulted in a drop in sugar exports from the Philippines to the United States from US$624 in 1980 to US$246 million in 1984. It is estimates that about 28 per cent of US nutritive sweetener market and about 45 per cent of the total industrial sugar market is HFCS of which 2 million tonnes is used by soft drink manufacturers, 0.5 million tonnes by the baking industry, and 1.2 million tonnes for processed food. Although the European Economic Community (EEC), for example, tried to restrict the expansion of HFCS production to protect local sugarbeet producers, the substitution trend has however continued Juma 189). The implication of these technological developments for use in agriculture is obviously uncertain at present. However, from a wider perspective substitution through industrial microbiology will reduce the importance of agriculture, where this is defined as the production of field crops associated with specific food and fibre systems for processing and distribution. In essence, these advanced techniques threaten to trivialize agriculture, transforming it into a source of organic matter for biomass (Goodman 1987). Now a new technological paradigm based on modern biotechnology is emerging, which will provoke radical restructuring of industries as they realign their activities to defend established positions and exploit new opportunities. To respond to this innovation, third world countries' diversification provides a vulnerable solution to the substitutionist challenge. For example, in places where high fructose corn syrup has replaced traditional sugar, sugar-processing interests have responded by developing competing sugar based sweeteners and diversifying into sucrochemistry.

Biotechnology may displace some agricultural export commodities from the third world and thus impacting the national economy and employment. The industrialized countries would find it economically and scientifically practical to substitute products currently imported from third world countries. In 1986, for example, while Sudanese farmers were preparing to harvest Gum Arabic for export, a New York company announced the discovery of a new industrial process for the production of natural gum of supposedly high quality than the farmed rubber of Sudan (Butorin and Brian 1990). Plant tissue culture offers increased possibility of substituting specialties with industrially produced inputs. Many high valued plant-derived products used for pharmaceuticals, dyes, flavuorings and fragrances are vulnerable to displacement as a result of current research (Juma 1989). The impact of a successful production of substitute impact mostly on countries that are dependent on exports of the natural product concerned. This is particularly destructive to economies in Africa, which depend entirely on single crops for most of their export earnings. While Africa was used to grow crops needed for Europe, in the emerging world order based on the new biotechnology, Africa will become dispensable as the North finds biotech substitutes for African crops. The South therefore needs to develop an agenda for compensation based on historical justice that can be tabled before the full deployment of the new biotechnology, which will reduce dependence of the North on the third world (Shiva 1993).

The introduction of biotechnology in Kenyan pyrethrum production serves as an example of the impact of technology on development. Kenya, for example, has been exporting a large share of its pyrethrum to the US, which accounted about 70% of her exports in the late 1960s and early 1970s but the entry of biotechnology based pyrethrums will irreversibly reduce the market enjoyed by pyrethrum growing countries. Ironically though, the countries involved in the production of pyrethrum supply the genetic material on which the research is based. With the spread of biotechnology to these countries it will be evident that those who have a competitive advantage in scientific and technological knowledge will control the global agricultural sector. Land and labour (which is abundant for third world farmers) become less relevant than they were when current economic theories were formulated (Juma 1989). Thousands of workers on sugar cane and palm oil plantations have already lost their jobs due to new enzymes and tissue culture techniques.

There is also a tendency towards proprietary rights and research secrecy, which mean that patented plants would be available only to those who could afford to pay royalty fees (Butorin and Brian 1990).

For these reasons, African delegates issued a joint statement with NGOs to FAO negotiations on the international understanding for plant genetic resource held in June 1997. They strongly objected to the image of the poor and hungry from African countries being used by giant multinational corporations to push a technology that is neither safe environmentally or economically beneficial to the community. These delegates voiced a rejection by African countries of a technology that kills the farmers' capacity to grow the food they need. This does not imply a refusal to western science, as long as that science and technology is based on the understanding of what is already there. It should be built on local knowledge rather than replacing and destroying it. It should also address the needs of the people rather than serving the interest of agribusiness (FAO 1997).

Seed, pesticide, and biotechnology companies are already positioned to introduce the new transgenic technology globally. Transitional companies such as Cargill, Mansato, and Pioneer Hi-Bred are all racing and targeting African, Asian, and European markets. Engineered crops, whether grown in the United States or in Africa are potentially harmful to the environment. Similarly, the hybrid seeds work in a way that they cannot be replanted because of the exacting requirements of machine harvesting and food processing. This is a disadvantage to resource poor farmers in third world countries who often take second generation hybrid seeds as a source of breeding material to be blended with their traditional varieties. These helps skilled local breeders who are mostly women be it in Bangladesh, or

Burundi, or Brazil to isolate useful genetic characteristics and adapt them to their immediate market. Biotechnology legislation, however, ensures that farmers cannot successfully replant their harvested seed because seed companies have panted genes for herbicide-tolerant or insect resistant. These make technology a trojan horse for the spread of genetically engineered crops to the South (Streinbrecher 1996).

FAO and agribusiness companies assert that biotechnology innovations will triple crop yields without requiring any additional farmland and thus saving rainforests and animal habitats. It is argued that the biotechnology revolution will mean less chemical use in farming. However, this assessment does not consider the other costs that accompany this technology such as social and environmental costs of large-scale industrial farming and other costs like water, air pollution, topsoil loss, and biodiversity loss. This assessment is also based on the agricultural economics of size, which ignores the significant advantage that small farms have in reducing input. For example, diversification increases efficiency because it allows complete use of inputs (Strange 1988). The Kofyar illustration in the previous chapter indicates that well managed alternative farming systems nearly always use less synthetic chemical pesticides, fertilizers, and antibiotics per unit of production than conventional farms. Reduced use of these inputs lowers production costs and reduces agriculture's potential for adverse environmental and health effects without decreasing and, in most cases, increasing crop yields and the productivity of livestock management systems. Biotechnology arguments fail to account for the declining yields now associated with the technological and chemical intensive 'Green Revolution' foisted on the third world farmers. In India and Nepal, for example, research indicates that there is a significant loss in yields after they peaked in the 1980s. Soil degradation and a proliferation of pests, typical of large-scale monoculture farming are suspected as the culprits in this decline (Lappe 1998).

The new plant biotechnology has followed the path of the earlier HYVs of the Green Revolution in pushing farmers onto a technological treadmill. Biotechnology can be expected to increase the reliance of farmers on purchased inputs even as it accelerates the process of polarization. It will even increase the use of chemicals instead of decreasing it. The focus of the research on genetic engineering is not on fertilizer-free and pest-free crops, but pesticide and herbicide-resistant varieties. Like the Green Revolution technologies, biotechnology in agriculture can be an instrument for dispossessing the farmer of seed as a means of production. The relocation of seed production from the farm to the corporate laboratory relocates power and value between corporations and farmers. It is estimated that the elimination of homegrown seeds would dramatically increase the farmers' dependence on biotech industries by about US$6,000 billion annually (Kloppenburg 1988). Biotechnology can also become an instrument of dispossession by selectively removing those plants or parts of plants that do not serve the commercial interest but are essential for survival of nature and people. Improvement of selected characteristics in a plant is also a selection against other characteristics, which are useful to nature or for local consumption. Improvement of partitioning efficiency is based on the enhancement of the yield of the desired at the expense of unwanted plants. The desired product is not however the same for rich people as it is for poor people, or rich countries and poor countries, or for efficiency. Agricultural systems or plants will be treated as 'unwanted' depending on what class of gender one is. What is unwanted for the better off, may be the wanted part for the poor. The plants and parts, which serve the poor are the ones whose supply is squeezed by the normal priorities of improvement in response to commercial forces (Shiva 1993). Biotechnology therefore is just anew approach to solving old problems and, as Kloppenburg observed, it is simply a new vehicle in which to drive down a familiar road and there is no miracle solution to it. What this technology is up to is the commodification of the seed. in addition to uncoupling farmers from autonomous reproduction of the seed.

Towards an Alternative and Sustainable Agriculture

The structure of corporate agriculture as described above prevents ecological research recommendations from being incorporated into management systems. The agricultural enterprise is unwilling to invest in sustainable technologies for which profits cannot be immediately captured. The emphasis for better yields continue and, in fact, in the 1980s this high technology approach has been epitomized by wide scale promotion of biotechnology claimed as the new technological fix that can thwart low productivity in the third world agriculture (Kenney and Buttel 1984). It is asserted that cell and tissue culture may be used immediately to accelerate the production of drought-tolerant and disease resistant crop varieties. Proponents contend that culturing and genetic transfer technology can quickly provide plant materials adaptable to most areas in the world, including marginal lands. The challenge for developers is how to transfer and adopt biotechnology to the social, economic and political conditions of developing countries. Given the economic conditions in these countries, it is fair to expect that biotechnologies promoted in debt-burdened developing countries may not be best suited to the local ecological and environments, but rather those most attractive to large markets of the industrial nations (Kenney and Buttel 1984).

Biotechnology proponents have asserted that the plant they produce may be resistant to many pests and are able to thrive in nutrient-poor environments. But the approach makes farmers especially peasant farmers increasing dependent on seed companies. Given the tendency of some companies to emphasize seed/chemical 'packages', farmers will automatically become dependent on chemicals needed to grow the seeds. This is true especially in the case of biotechnology that tailors crops to specific needs (such as herbicide-resistant crops). In such situations, farmers lose their autonomy, and their production systems become governed by distant institutions over which rural communities have little control.

CHAPTER 5

INTELLECTUAL VERSUS INDIGENOUS PROPERTY RIGHTS

This chapter analyzes theoretical and empirical aspect of the current debate over the uses and benefits arising from genetic resources, commonly known as biodiversity. The chapter addresses the current global dilemma: should one treat plant genetic resource as a vital source of germplasm to support sustainable agriculture or as communal property of those who hold them at present or those whose ancestors once held them. The rights especially for indigenous or farmers[3] regarding the use of these genetic resources and the benefits that arise from them have often been misunderstood. The nonmaterial nature of the genetic code, and the increasing importance of the crop genetic diversity for agriculture make the conflict over rights in crop genetic resources especially complex[4] (Juma 1989). The right of farmers to the use of resource is important to sustainable development of agriculture because without autonomy over such resources, the incentive for farmers to have along over their preservation wane (Chambers 1987). It is necessary to seek ways to identify a practical mechanism to reward indigenous farmers for creating and conserving traditional crop varieties and other land-races. Cleveland and Murray (1997) suggest that the advocates of both indigenous and northern viewpoints tend to oversimplify the issues and misconstrue indigenous peoples' conceptions of intellectual property rights. Because of northern notions' dominance of intellectual property rights in these discussions, alternative forms of rights may be more effective bases for resolving these conflicts.

The biodiversity[5] found in the diverse varieties of food crops and their wild relatives sometimes called genetic resources is critically important for global food security. (Rodda 1993; FAO 1997 It supports the continued productivity of crops that provide most of the food supply for the planet's six billion people. Farmers or folk crop varieties developed over many generations by indigenous farmers are important component of global crop genetic resources for use by both northern and indigenous agriculture. International controversy continues over the control of genetic resources and the distribution of the benefits from their use (Dove 1996)

Farmers in developing countries are not rewarded for their contribution to the northern agricultural production since land-races are considered common heritage. The patent system in the north leaves no room for reward for land-races (Shiva 1991). While others contend that crop improvement will seriously be hindered when the principle of free availability of genetics worldwide is abandoned and that, it is almost impossible to trace what the specific contribution of land-races or related wild species has been to an advanced breeding line. In spite of the above controversies, many authors of various disciplines on genetic resources give two simple assumptions. Innovators are motivated by the prospect of reward and second, society benefits from innovation by virtue of the economic and cultural growth (Dove 1996; ,Kothari 1994, Gupta 1994).

Attempts to resolve the crop genetic resources debates have focused on various discussions in which many different views are presented. One perspective is that inadequate intellectual property rights protection guts the incentive to innovate, which in the long run dampens economic growth and cultural advance. This means that if owners of intellectual property rights are unable to enforce the terms and conditions under which their innovations are made available, then owners of intellectual property rights will not be willing to put their interests at risk. The second perspective is that by allowing commodification of information, intellectual property laws may facilitate a market in which control over the use and dissemination of information could be accumulated and held by a relatively small number of private entities. Another perspective is that farmers rights interpreted in terms of compensation arising from past, present, future contribution of farmers in conserving and making available plant genetic resource will invoke very complex negotiations that depend on the willingness of northern countries to assess the value of plant genetic resources (Greaves 1994). In this discussion, I do not take either perspective, instead, I explore the problem of the incompatibility of farmers' rights with intellectual property rights, while at the same time recognizing that a practical solution may be possible, for example, compensation based on innovation efforts not ownership. The challenge however, will be to provide incentives that preserve, create and enhance biological diversity and also compensation that will at the same time allow farmers to make use of modern plant genetic resource such as markets, savings, swapping and multiplication for breeding purposes without violating intellectual property rights.

Crop Genetic Resource

Folk varieties are the basis from which all current crop varieties have been developed and they remain an important part of the crop genetic resource on which modern industrial agriculture continues to rely. Evidence suggest that the rate of loss of folk varieties has increased with the modernization and internationalization of agriculture (Cleveland and Murray 1997). The development of modern formal plant breeding after 1920 resulted in modern varieties (varieties that responded with high yields to optimal growing conditions that often included high level of inputs) but which probably as already discussed above led to an increase in the rate of loss of folk varieties. After World War II, the spread of industrial agriculture[6] in the third world through the Green Revolution greatly increased yields of wheat and rice. It also made possible for world food production to increase in tandem with the human population, while at the same time increasing the rate at which modern varieties replaced the folk varieties (Evans 1993).

The issue of crop genetic resource gained prominence in the international fora in recent decades because crop genetic resource professionals see the ongoing loss of folk varieties. The desire to maintain food production in the face of increasing environmental and social constraints and recent advances in agricultural biotechnology has justified increased investment in collection and characterization of folk varieties to facilitate their use as raw material for breeding modern varieties (Plucknett et al 1987). Though most breeders select new crop varieties from material that has already been improved by formal breeding, folk varieties are seen as a very important source of genetic diversity. Their potential importance has increased with growing recognition that future demand for increased food production will force reliance on more marginal growing environments. In addition, recent developments in biotechnology have made genes in folk varieties and their wild and weedy relatives much easier to identify and manipulate. Folk varieties contribute to production stability in indigenous agriculture[7] because through local ongoing natural selection by the environment and artificial selection by farmers, they are adapted to often-stressful low-external local growing conditions (Evans 1993). Folk varieties are also valued by farmers because of the cultural values which they are imbued such as their symbolism in religious ceremonies (Clevelland 1997). Because modern varieties are grown under more uniform conditions, requiring a higher level of external inputs, their yield variability may be greater because of variability in weather, pest and pathogen evolution and price of input.

Intellectual Property Rights

Of major concern is the recent expansion of intellectual property rights held by northern firms over crop varieties they have developed. Intellectual Property Rights[8] refer primarily to international and national legal mechanisms used to protect corporate and individual interests within a profit motivated science and technology system. The term is ineffective when applied to local communities and their knowledge, as it does not recognize its status as a community responsibility rather than private property (Appleton et al 1994).

Intellectual property rights in the northern world spring from European philosophical traditions that see individual identity and liberty as tenure. However, western legal concepts do not generally include the notion of collective rights. The United States was probably the first nation state in 1930 to provide modern intellectual property rights protection for new plant varieties. To date most of the northern countries have applied different standards of protections to folk varieties as compared with improved germplasm and modern varieties. There is also insistence of free access to folk varieties and their wildy and weedy relatives as common human heritage, with no recognition, control or compensation to the farmer breeder who developed them. In contrast improved germplasm, and their genetic components are regarded as private property and monetary compensation is given to individuals or corporations who manipulate folk varieties in their laboratories and experimental plots to create modern varieties (Cleveland and Murray 1997).

These perspectives rest on the assumption that folk varieties are the common heritage of mankind and that the free flow of biological resources is in the best interest of all people (Brush 1992). These assumptions are also stated as values shared by all people although there is usually little or no evidence provided in support, especially for non-industrial societies. From this viewpoint intellectual property rights as currently used and defined by industrial countries are taken as valid for all people and all times. The western industrial nations have been exerting pressure on third world countries most of which do not recognize patents on living things to accept industrial notions of intellectual property rights and create and enforce laws supporting them. On the other hand, conventional economists, agronomists, and intellectual property lawyers consider intellectual property protection of innovation critical for economic growth and lack of intellectual property rights a major impediment to development of third world economies (Kothari 1994).

Indigenous Intellectual Property Rights

FAO defines farmers rights as rights "arising from the past, present, and future contribution of farmers in conserving, improving and making available plant genetic resources, particularly those in the centre of origin/diversity" (FAO 1997; 57). These rights are vested in the international community as trustees for present and future generations of farmers for the purpose of ensuring full benefits of farmers and supporting the continuation of their contributions. This resource include rights to control over folk varieties, knowledge of folk varieties, financial, technical, and educational resource to develop folk varieties, and the right to control their own farming systems including land and access to markets. This perspective that reflects the viewpoints of indigenous peoples have been strongly resisted by many industrial governments, private seed companies and biotechnology companies.

However, Cleveland and Murray (1997) assert that data suggest indigenous people have concepts of intellectual property in folk varieties and take an active and conscious role in their creation, maintenance, and dissemination. Holders of intellectual property in indigenous society include individuals and groups based on residence, kinship, gender, or ethnicity (Greaves 1994; Juma 1989). They argue that dispute over rights, in particular intellectual property right in world crop genetic resource will be facilitated by considering farmers' values in a broad perspective and on equal footing with the values of industrial agriculture. According to these perspective, indigenous communities will have to adopt statements of principle based on international, cultural and environmental rights in order to level the bargaining ground.

Historically, the genetic resource fitted well into the existing premises that were brought to bear against international agricultural research institutions. These premises were related to the long standing, social-justice oriented view of developing countries poverty and underdevelopment, in which mass poverty was considered to be the result of oppressive social structures and social policies invoked in the interests of dominant groups (FAO, 1997). This perspective generated significant political impact, particularly on the Group of 77 developing countries, and their New International Economic Order (NIEO) that had been proclaimed in several United Nations fora in the 1960s and 1970s. The social justice perspective was strengthened by the Rural Advancement Foundation International (RAFI) which lobbied within FAO against the North's dominance in the exchange and use of genetic resources and against the neglect of the rights and needs of small farmers. The concern of indigenous farmers worldwide for safeguarding their rights in crop genetic resources appears to have grown as plant breeders' rights, patents, trademarks, and other industrial-world forms of intellectual property rights were increasingly perceived as threatens and alienating them from control of and denying them compensation for these resources. This includes use of genetic traits desirable for commercial plant breeding and industrial agriculture and of folk variety names and foods without permission, compensation or apparent recognition that indigenous farmers may have rights to these resources (Fowler 1994).

From the 1970s, advocates of indigenous farmers in the north helped raise awareness on this issue. Mooney and Fowler (1990) were on the forefront in advocating a voice for an indigenous viewpoint in the international fora such as FAO (1997). Various NGOs such as the RAFI based in Canada and the Genetic Resource Action International (GRAIN) based in Spain have worked on behalf of indigenous farmers. Indigenous farmers and supporters have responded to the pressure from the north on the use of intellectual property rights as the standard of classifying rights in crop genetic resources that they be compensated when folk varieties and folk variety names are used or marketed by others

(Cleveland and Murray 1997).

These efforts helped shape the issue of genetic resources as it stood throughout the 1980s. Among the advocates of the genetic resource issue was Mooney (1990) who first identified the political power of the users of the genetic resources: rich industrial countries, their multinational corporations, privileged social classes, government and quasi-government (like CGIAR) officials that comfortably supported them. According to Mooney, the victims were third world countries and smallholder farmers. Mooney further argued that genetic resources are a strategic commodity instead of a freely exchangeable public good by making rough calculations of their value for the Northern agro-industry, particularly the biotechnological sector. These provocative publications provided many NGOs with ammunition in the battle against seed multinationals and agricultural bureaucrats. Throughout the 1980s RAFI and GRAIN had became strong critics of genetic resources issues and were actively involved in international arguments on the conservation, use and access to genetic resources. Many point out that the recent focus on intellectual property rights disproportionately on protecting corporate or individual knowledge in the area of biological products, leaving a whole range of cultural or community knowledge open to exploitation. Genetic resources are often incorrectly referred to as 'raw material' for biotechnology, whereas in reality they are the products of intellectual, cultural, and environmental contributions of local innovators, both men and women. Describing them as raw material allows dominant science and technology systems to exploit not only the matter but also the people, as they are seen to belong to no one in particular. An exploitative asymmetry is therefore created. When information is collected from Andean women peasants and Amazonian native peoples, for example, scientist consider it to be the common heritage of human kind, a public good for which no payment is appropriate or necessary. However, when the information is processed from and transformed in the laboratories or factories of the so-called developed nations, its value is enforced by legal and political mandate (Fowler 1994). Appleton (1994) warns that in the era of biotechnology, all products and process could become patentable material, and countries such as the United Sates could be in a position to act against any country that did not provide exclusive opportunities for their corporations protected by their national laws. As noted by Greaves (1994), local knowledge, now far more than in the past, is under real or potential assault from those who would gather it up, strip away its honoured meanings, convert it to a product, and sell it. Each time that happens the heritage itself dies and with its people.

By the 1980s breeders, geneticists and representatives of the agro-industry started to participate in the debate. Their arguments were based on the conviction that because genetic resources were highly important in safeguarding international food production, to treat such resources as strategic economic resources would hinder scientific progress in both public and private sector research institutes. Thus genetic resources that are used to save millions must be treated as a scientific, politically neutral and freely exchangeable good, from which developing countries benefit even more than countries in the North. Northern countries only take small samples and that indigenous land-races have been replaced by Green Revolution cultivars without which Asia and Latin America would still be starving as they did before the Green Revolution. Supporting the view that, genetic resource exploitation mainly benefits the third world countries.

However, RAFI and GRAIN reacted to these arguments by saying that CGIAR were the main driving forces behind the Green Revolution and the creation of monocrops contributed to genetic erosion and destruction of biodiversity. Within this same period, historians, social scientists, anthropologists, biologists and economists joined the debate. Historians such as Lucile Brockway (1988) linked colonial interests with genetic resources exploitation. She used the 19th century British Botanical gardens and how they took over much of the work of exploring and collecting from individual 'plant hunters' and how it acquired the technical ability to improve and adopt plants for commercial production. The result of this was a global division of labour in agriculture dominated by the North creating a centre-periphery model. Kloppenburg (1994) concurs with Brockway in analyzing the dependency relationship when he asserts the continuous leadership of the northern states and their scientific community in the appropriation of genetic and cultural information of Southern people in subsequent centuries.

Seed companies such as Dupont and Mosanto insisted that competitive positions of United States industry in biotechnology would be improved if there were international conventions that would provide greater uniformity with respect to patentability and property rights. While this rhetoric is about agricultural development in third world, Shiva (1993) argues that enforcement of strong patent protection from monopoly ownership of life processes will undermine and under develop agriculture in third world countries. This is mainly by undermining the cultural and ethical fabric based on agriculture in which the fundamental life processes are treated as sacred and not as commodities to be bought and sold on the market. Shiva (1993) also argues that corporate demand to change a common heritage into a commodity and to treat profits generated through this transformation as property right will lead to erosion not just at the ethical and cultural level, but also at the economic level for the third world farmers. Because, Third World farmers are consumers of western technology and industrial products of agro-business, patent protection displaces the farmers as competitors, transform them into suppliers of raw material and makes them totally dependent on industrial supplies such as seeds. Therefore intellectual property rights in agriculture will marginalize not just the farmers but also the national research and breeding system, which has been built so carefully (Shiva 1993).

Moreover, the rapid expansion of genetic engineering biotechnology in recent years has led to new classes of patent claims by northern corporation on genetic and intellectual resources that belong by right to communities in the South. These 'patents on life' include plant varieties cultivated and used by indigenous communities for thousands of years, as well as genes and cell lines obtained under false pretext from indigenous peoples themselves (Kloppenburg 1991). This has had great impact on the self-determination of peoples and their human rights; on biodiversity, relationship between science and society, the growth of bio-tech industry and developments in North and South (Kloppenburg 1991).

Farmers' Rights: Compensation

The concept of farmers' rights resulted from debates within FAO that explicitly recognized the fact that a commercial variety is usually the product of applying breeders' technologies to farmers' germplasm. This recognition of the potential commercial value of land-races and wild relatives from developing countries, led to questions about the property protection over commercial varieties on the one hand and farmers germplasm on the other. With the enforcement of the convention on biodiversity, the political struggle over genetic resource has centered on how these incompletely defined rights might be realized. Both conservationists and advocates for indigenous people and farmers' interests such as Posey (1990) propose that farmers and herbalists with plant resources be compensated for providing industrial users access to those resources. Proponents suggest various schemes and mechanism for 'sharing the benefits'. They argue that intellectual property rights regimes are one possible means for compensating farmers for their contributions (Fowler (1994). These proposals are based on the utilitarian rationale that such farmers should have incentives to encourage them to continue to conserve and develop important plant genetic resource and associated knowledge and practices.

According to Kloppenburg (1994), never in history has agribusiness been willing to compensate for the use of genetic resources originating from the South. But now, pressured by environmental groups and Southern stakeholders, agribusiness increasingly see that its in their own interest to pay for preferential access to genetic resource materials, of which the Body Shop International is a concrete example. These arrangements underlie the principle that genetic material can be acquired as a normal good in commodity markets, within the existing framework of intellectual property protection. This legitimates the status quo of centuries of appropriation by the North of Southern treasures, while almost completely ignoring indigenous people or local communities. However, Kloppenburg (1991) seriously doubts whether farmers or indigenous people will benefit very much from the establishment of prospecting payments. This skepticism is based on the fact that existing institutional and contractual arrangements do not address the most contentious issues in the bioprospecting debate. For example, on what legal theories and sources of law are claims to ownership and control of biological diversity justified? Will establishment of commodity values for biological organisms lead to conservation of sustainable development? And what are the relationships and respective rights of indigenous peoples and local communities, nations and the 'global public' to biological diversity and local knowledge? Shiva (1993) contests bioprospecting because of the negative development it could provoke. She wonders whether there will be an added cost for societies of developing countries when they sell the right to use their biodiversity? For example, if the gene responsible for the high protein content in amarath is put into rice, an increasing acreage of rice could contribute to the disappearance of the valuable crop amarath and according to Shiva, losses of this kind would never be compensated by the payment received for bioprospecting.

Although the issue of farmers' rights is short and recent, by the 1990s there was a shift in the debate of farmers' rights from the issues of economic compensation to social economic rights. This shift occurred because it had become apparent that industrialized countries would not accept farmers' rights in terms of intellectual property. In addition, NGOs (such as RAFI and GRAIN) had realized by then that a mechanism in which indigenous communities or individuals could obtain intellectual property rights would probably be 'difficult' to implement and would restrict access to genetic resources (GRAIN 1991). GRAIN (1991) also argued that farmers' rights could be better connected to capacity-building at the grassroots level, providing local communities with their own tools to improve stable, low-input production systems rather than being connected to an economic compensation mechanism. GRAIN therefore emphasized social economic rights. This shift in the discussion was also based on the realization that these rights, as an intellectual property concept would imply an extension of the western paradigm on intellectual property with its focus on ownership. Acquirers of knowledge have power, technology, inside information, and sophisticated economic systems that allow them to take unfair advantage of knowledge innovators, particularly women, who have less access to power structures. Applying existing patent and copyright laws to local knowledge is not only impossible but also impractical for various reasons: there are no identifiable inventors, all traditional culture is already in the public domain and protection would only last a finite number of years. The present purpose of patent protection is to encourage profit for a few, but not to sustain communities and the environment as living systems. Appleton (1994) suggest a new legal instrument, one that confers ownership on those who create, develop, and enhance it and one that recognizes the differential access of women and men to political decision making structures. This instrument will include ownership of, and control over, knowledge that is commonly held rather than individual. This kind of instrument can only be developed with an active participation of those who posses the knowledge, both men and women.

Gupta (1994) suggests that many local farmers practicing modern agriculture make selections of off-type plants and through recurrent selection develop high-yielding/disease- or pest resistant varieties. Farmers in India have developed through deliberate selection and breeding and breeding, over 50, 000 varieties of rice with motivations ranging from survival in harsh conditions to cultural preferences and ritual requirements (Shiva 1993). These innovations may deserve the same protection as is available to any plant breeder, whether in private or the public sector. In addition, local communities may use a modern variety in one season and grow local land-races in another season. Such farmers combine traditional and modern elements all the time and therefore may not very much appreciate the academic debates, which try to dichotomize these subsets of human ecology. In the context of Africa, Latin America and Asia, the term 'indigenous' does not make sense. Gupta (1994) points out that a community may not want someone else to use the same label as it uses for its crafts or genetic material, but it may not exclude others from learning or using it.

This does not imply that they do not have intellectual property rights concepts because as many contributors to the debate suggest, many local communities have had some kind of intellectual property right. The problem arises however, when communities that did not object to sharing of their material resources and knowledge about them are 'forced' to adopt modern institutions of property rights because they would suffer otherwise. Many feel that this intrusion is uncalled for and argue that the state and the markets which failed to protect the resource rights of these communities in the past must come to their rescue without resorting to modern mechanism such as intellectual property rights. Kothari (1994) argues against monopolization of knowledge through biospropecting whether by multinational corporation or by traditional faith healers. Instead Kothari (1994) proposes a system of individuals and community intellectual rights that may make sharing of knowledge compulsory but also confers responsibility upon the recipient of that knowledge not to unfairly appropriate it.

Many doubt whether intellectual property is a proper mechanism for incentives. Considering a fundamental problem that may arise when indigenous farming communities try to commercialize their plant genetic resources, they may be forced to adopt some of the rules of the industrialized world, thereby changing the nature and goals of their indigenous societies. Not only does this mean they are in danger of 'losing their souls' but also it places them at a clear disadvantage in striking bargains. It also has to be remembered that indigenous communities for the most part are small, lack financial resources or political power, and are divided among themselves in regards to goals and means of achieving them. Cleveland and Murray (1997) clearly note how indigenous communities and their national governments differ over who should control and profit from their plant genetic resource. Brush (1996) points out that drug and seed companies in industrial countries profit by excluding others from using their products, farmer's and herbalist have no such legal rights. Genetic resources in farmers fields and indigenous people's forests are treated as public good or common heritage, while genetic resources in industrial laboratories can be treated as private property.

Brush (1992) points out that farmer's 'own' their knowledge and seeds, because these cannot be taken without their consent. However, Brush (1992) questions the wisdom of granting rights to farmers to commoditize their knowledge and the crop germplasm in their fields. He suggests an alternative through nonexclusive and perhaps non-market compensation and that, anthropologists who have worked with farming cultures where these biological resources are abundant should have a major voice in the discussions. Dove (1996) disagrees with the views contested by Cleveland and Murray (1997) that indigenous communities do not create and maintain biodiversity, a view that grounds traditional agriculture as static. This perception of stasis sees indigenous people as not actively involved in contributing to crop genetic diversity and therefore have no claim to compensation when outsiders appropriate these resources.

It is sometimes stated that indigenous farmers have no conscious sense of intellectual property rights either in folk varieties in particular or in biological resources in general. For example, it has been suggested that uncollected and uncharacterized genetic resources are customarily not considered to be property, nor are they treated in any way that suggest an implicit set of restrictive property rights (Brush 1992). This view is challenged by evidence which suggests that the conscious efforts of farmers in selection and maintenance of folk varieties forms that basis for their assertion of intellectual property rights of their folk varieties within their own societies at individual and group levels. For example, Richards (1996) has given a clear description of how the Mende of Sierra Leone consciously and extensively manage their crops and crop varieties on the basis of agronomic criteria. In addition to giving credit to individual farmers for the discovery of new rice varieties, for the Mende also rice genetic resource is a manifestation of ancestral blessings as distinct to private wealth inherent in the market economies. Ethonobiological knowledge documented supports the hypothesis that there are common cultural patterns in the application of names for plants and animals in systems of ethnobiological knowledge. Knowledge about folk varieties is often distributed unevenly with gender and age being a common determinant. For example, Aquarana women's knowledge of plant varieties is much greater than of Aquarana men (Berlin 1992). It is this unequal division of knowledge upon which intellectual property rights within a culture are based. When farmers share seeds with outsiders it should not be assumed that they lack the concept of intellectual property rights in their folk varieties. But may rather reflect an implicit assumption that those who receive them may treat them with the same respect as the farmers who gave them and not use them for commercial purposes. The common assumptions of industrial agriculture have been that folk varieties taken from indigenous farmers are used in crop improvement for potential benefit of all people. This, however, ignores the damage to the folk varieties in the eyes of indigenous people and the fact that farmers may want to speak for themselves.

According to Yano (1993), industrial-world intellectual property rights mechanism have been created to protect 'readily identifiable, differentiated contributions of individuals and corporations and now these mechanisms have been advocated for indigenous people on grounds that this will be faster and more economically efficient than trying to create a new regime. Dove (1996) differs in his view when he points out that although it is the indigenous communities that have maintained the biodiversity that the world values precisely, they and the resources they manage have been marginalized. Because they have been marginalized. Dove (1996)argues that any attempt to apply intellectual property rights to indigenous people is impractical. Any compensation will be skimmed off by nation-states that do not share their goals and if applied are likely to be counterproductive in that compensation will only further draw indigenous people into the world-economy. Brush supports this view by asserting that industrial-world notions to folk varieties is seen as the introduction of 'a tool of capitalism' to indigenous farmers who are 'in some ways pre-capitalistic' because their rights are valued by non-market mechanisms while breeders' rights are valued by market mechanism.

According to Cleveland (1997), recognition of indigenous rights by the dominant industrial society may often not include rights of indigenous peoples to manage resources in their own way because resource management is considered to be based on scientific principles that are not culturally relative. The connection may be achieved by demonstrating indigenous peoples' knowledge and sustainable management of their environments and biological diversity. Agenda 21 of the UN Conference on Environment and Development assumes that indigenous farmers conserve biodiversity and crop genetic diversity and calls for programs and policies supporting in situ conservation of crop genetic resources in farmers' fields and local ex-situ conservation in community seed banks. Article 8(j) of the convention on biodiversity calls for signatories to 'respect, preserve and maintain knowledge, innovations and practices of local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity' and to 'encourage the equitable sharing of benefits arising from the use of same (Streinbrecher 1996).

Alternative Approaches to Indigenous Farmers' Rights in Folk Varieties

The above perspectives have suggested that the application of northern-world views of intellectual property rights cannot serve the interest of the indigenous farmers. Alternative approaches challenge the dominance of industrial-world views as regards crop genetic resources and attempt to establish a basis for the discussion of rights at a more general level. Cleveland and Murray (1997) strongly point out that rights are often interpreted in ways that privilege the industrial-world viewpoint allowing the dominant powers to describe even the scope of the debate. For example, when it is stated that common heritage implies reciprocity, the fact that the terms of 'reciprocity' have been determined by the industrial-world users of those resources are often ignored. The supporters of northern-world view argue that indigenous farmers have been repaid for use of their crop genetic resource by the development of modern crop varieties that eventually make their way back to the farmer (but at non-affordable prize). This is based on the assumption that western development experts and plant breeders always know what is best for the farmers. Evidence show that development based on these assumptions have failed in most of the developing countries, and there is need for a fundamental shift as was discussed in the introductory chapter of conventional approaches to resource use and sustainable development. The sustainable livelihood approach as advocated by Kloppenburg (1991). and Chambers (1989) calls for reversals in development. Development that would be more in keeping with the needs of local inhabitants and the environment, where biodiversity contributes to the strategy of many poor people to reduce risks, insecurity and dependence not by simplifying or standardizing but by complicating and diversifying their livelihoods and social relations. Chambers therefore stated that diversity is not a static quality to be preserved through and protection, but a function of permanence of change. In order to employ biological and cultural diversity for diverse developments, Chambers emphasized the need for a development paradigm, which recognizes the validity of local people's knowledge, analysis, experimentation and learning. In more general terms Kloppenburg (1991) calls for reverse in development which would not start from the needs of the Northern world and for more productive crop varieties or for new drugs, but from the need of indigenous peoples to survive. Shiva (1993) on the other hand suggested for the establishment of a system for the free sharing of local indigenous knowledge and biological resources among local communities in developing countries, independent of the agro-business. In this way, biodiversity could benefit the development of local communities without losing control over their own resources.

CHAPTER 6

WOMEN AND SUSTAINABLE AGRICULTURE

The introduction of modern agricultural technology impacted on women in developing countries by destroying genetic diversity upon whose their livelihoods depend. In preceding chapters, these impacts are clearly illustrated. This chapter attempts to focus on how modern agricultural technology affected the ability of women to sustain their livelihoods socially and economically in different parts of Africa. A case study of Kenyan women will be used to illustrate the roles of women in the sustainable agricultural development and how modern technologies such as the Green Revolution and biotechnology has undermined these roles. In spite of the various international efforts to recognize the vital role played by women in the conservation and sustainable use of biological diversity, women are still restricted from the benefits of these technologies (Shiva and Dankelman 1992). The shift that recognizes women as keepers of biodiversity coincides with the recent interest in indigenous knowledge, progress in modern biotechnology, and a rush towards a world wide implementation of intellectual property rights (Fernadez 1992). All these changes have affected women differently depending on where they are located. In particular, the impact of biotechnology on women depends not just on the characteristics of this technology but also on the context in which it is developed, the interest of those who introduce it and the situation of those whom it affects (Appleton 1996). In assessing the impact of biotechnology on women two crucial questions need to be addressed. First, who controls the new technologies and for whose benefit? And, second, will modern agricultural technology help women develop sustainable agricultural methods that allow them to sustain the environment and their livelihoods as well?

Although there is diversity in household production patterns, women in all regions of the world play a predominant role in household food security through agricultural and food production. It is estimated that women in developing countries spend up to two thirds of their time in traditional agricultural work and marketing, with their work hours tending to exceed those of men. In these countries, women in rural areas grow at least 50 per cent of the world's food. Women work in all aspects of cultivation, including planting, thinning, weeding, applying fertilizer and harvesting as well as post-harvest activities such as storage, handling, stocking, marketing and processing (Sachs 1993 and Shivaland Dankelman 1992). It is for these reasons that the UNDP/World Bank projects in Burkina Faso, Kenya, Nigeria and Zambia on raising the productivity of women farmers in Sub-Sahara Africa concluded that women's participation was so important to African agriculture that initiatives to raise the sector's productivity cannot afford to ignore them. In addition, they are now cultivating crops such as coffee and other cash crops and taking on other tasks such as land clearing traditionally performed by men. This is partly due to males migrating away from farms in search of more remunerative activities. While women produce much of the developing world's food supply and are the backbone of food production and provision for family consumption, their productivity is generally low and based on long hours on small landholdings. They also have restricted access to training, technology, credit and inputs, and, for most part, use traditional methods (Zweizel 1995).

In the foregoing chapters, we discussed how food security of local and global communities is based on biodiversity in fields and forests. Biodiversity is of economic value for plant breeding and new industrial uses. But the centres for genetic diversity most of which are located in the South are threatened with extinction.. At the local level, biodiversity loss threatens the sustenance of local communities, as biodiversity provides food, fibre, medicines and other products that ensure subsistence and income. Because of the social differentiation according to gender, women in most societies play a significant role in managing the diversity of the ecosystem, since they are responsible for maintaining the livelihood of the family. Women have developed multiple strategies for farming systems, almost all of which are based on a sophisticated management of genetic diversity (Zweizel 1995).). The women are the real experts on biodiversity. To spread the risk of crop failure, women cultivate a wide variety of traditional crops, and practice intercropping and crop diversification in the field and their kitchen gardens. Almost all diversity within reach of rural societies is used, developed and maintained by women. The so-called wild species that require little external input and capital are part of the local agro-system and are of vital importance to the poor. For women in Burkina Faso the leaves and trees in the Sahel, alongside wild roots and tubers, grasses and herbs, form an important of the daily diet of their families, and are also a welcome source of cash income (Appleton 1994).

In most societies in Africa, Asia and Latin America, the care of seeds has traditionally been in the hands of women, who develop a broad spectrum of well-adapted crop varieties. For example, older women farmers of Quechua communities of the Andes posses a rare knowledge of plant breeding (Appleton 1994). Instead of propagating the potatoes via asexual reproduction, these women use true potato seed, a practice that they learned from older people who taught them about the fruit of the potato, which contains the seeds. Using seeds for propagation enables women to breed new varieties with characteristics which they themselves choose. Before harvesting potato crop, women collect the fruits and store them in a large ceramic bowl outside the house where they remain until the following season to promote the production of chemical that activate the dormant seed. After harvest women sort out 'tuber-seeds' by shape and colour and other desired characteristics often dividing them into as many as 12 types, which are distributed among the children who plant them as food (Appleton 1994). The vital role of women in selection and plant breeding has given them a position of influence, power and respect. However, the modernization of agriculture and the growing emphasis on market-based transactions are contributing to the erosion of local knowledge systems. Similarly, with further modernization of agriculture and the destruction of biodiversity. Both women's knowledge and their status as keepers of the seed are being eroded. The young generation of the Quechu community may not possess the knowledge that the older generation passed to them. With the emergence of modern biotechnology, living resources have gone from being the very basis of sustenance to being the 'raw material' for industry. Biologists, agronomists, social anthropologists and other scientists in the service of the industry ransack the forests, bushes, fields and markets of the south in search of genetic material and the knowledge of local people. However, these scientists often overlook the fact that women are the plant breeders and experts on local biodiversity. In most cases they fail to perceive women's knowledge as real knowledge, often referring to it as 'intuitive' and 'primitive' (Fernandez 1992).

Kenyan Women Conserve Genetic Diversity

Cultural diversity and biological diversity are two sides of the same coin. Living diversity in nature corresponds to a living diversity of cultures. With cultural and environmental changes, both biodiversity and indigenous knowledge systems vital to sustainability are being lost at an incredible rate UNEP (1994). One reason for this rapid loss is the introduction of western market-oriented agricultural and forestry technology that is not only displacing but also eliminating local practices in favour of monocropping, large scale agriculture and cattle raising. But this has also led to degradation of natural resources, poorer loss of informal channels of communication. In addition to these changes, structural adjustment policies of the 1980s encouraged farmers to increase production of crops for export, such as coffee or cotton (World Bank 1991). With this change of emphasis, women's land that was previously cultivated for crops may be alienated and as a result women can lose both food resources and income. In cases where women already help produce cash crops, an increase in cash crop production may mean they have less time and energy to grow and prepare food for their families (Shiva and Dankelman 1992).

Positive Impact of Agricultural Technology on Women

In some cases measures designed to expand agricultural output can lead to increase in employment and credit opportunities. In certain cases women earn incomes by producing or processing cash crops as wage labourers. The extent to which women can benefit from these opportunities depends, however, on how policies impact on the sexual division of labour: whether women can exercise control over the income earned and the degree of legal protection of women and men from exploitation. The primary objective of a new agricultural technology (such as crop varieties, cultivation methods and technologies/mechanization practices) is to save time and increase efficiency without threatening women's and men's jobs in farming. Irrigation technology, for example, can increase crop production and make more water available to households and livestock. This greatly reduces the time spend collecting water. In Tanzania, for example, an irrigation project reduced by half the time women spent collecting water thereby releasing sufficient labour to increase the area cropped by 20 percent (FAO 1990). On the other hand, technological changes in agriculture can affect women negatively as will be illustrated throughout this chapter.

There are examples that show that when women have a high degree of control over their means of productions (labour and other forms of organizations) and are in a position to influence the development agenda, they usually opt for a diversity of animals, crops and varieties. Women's deep concern for maintaining diversity in their surrounding environment and their general concern for the quality and sustainability of natural systems is an intimate part of their relation with their perception of their environment tends to be comprehensive and multidimensional. Men's knowledge tends to be one dimensional, focusing on narrow areas such as cultivation of a single high yielding and commercially profitable crop. In the context of biodiversity, there are also differences with respect to the decisions taken. For example, when deciding which seed characteristics and varieties to preserve and what new combination to search, women tend to consider many different complementary and interrelated advantages such as flavor and cooking time. On the other hand, male farmers who employ modern methods and agricultural research scientists in general usually look for the ideal genetic material for a more limited range of purpose such as high yield and a good market price (Zweizel 1995).

As Jiggins (1994, p.12) points out, "the challenge is for scientists to accept that men and women farmers are germ plant consultants and curators and to develop field methodologies and management strategies that support farmers in these roles". Women have traditionally played a silent and central role in the management and sustainable use of biological resources and the life support systems. Women's relation with the environment is holistic, multidimensional and productive (Shiva 1989). However, western technologies undermine the control women have over these systems. Once this happens, the conservation of biological biodiversity will not be possible if women are marginalised from resource management and production.

Biodiversity Conservation: The Kenyan Situation

East Africa is geographically and ecologically diverse with ecosystem ranging from deserts to tropical rainforests that creates a strong diversity of habitats. For example, Kakamega forest in western Kenya, Guinea-Congolean, mount Kenya and Aberdares are amongst the areas with high species diversity. Thus Eastern Africa has been considered as a center of genetic diversity exemplified by the distribution of many wild relatives of cultivated plants, including coffee, sorghum, millet, *vigna*, sesame, lablab (*hyacinth bean*), and others. It has been estimated that there are about 8,000 to 9,000 species of plants in Kenya. Two thousand of these are trees and scrubs of which 5% are considered endangered while 8% are considered rare (juma 1989). At community level, rural people are faced with serious depletion of biological diversity upon which they rely so much. Many externally led programs often fail to involve both the communities in planning and to identify them as the intended beneficiaries of the initiatives and more often these programs have institutionalized academic objectives, which override the communities' conservation needs and priorities. Many efforts fail to understand that these communities are custodians of biodiversity and that they know its value and potential (Shiva 1992).

Rich biological diversity found in the vast indigenous forests, which sprawled the country and were relatively undisturbed due low population densities, characterized pre-colonial Kenya. The diversity of primitive cultivators, land-races and wild species gave rise to thousands of plants being used as sources of local food. These food plants which became part of folk culture, included wild fruits, annuals and perennials, potherbs, roots and tubers, legumes, vegetables, aquatic weeds and partially domesticated crops of all types. The list of edible plants and local crops used by all the ethnic groups in Kenya probably number into hundreds, although no comprehensive list has been compiled for the whole country. All the crops and plants are highly adaptable to their environments and have developed disease resistance through co-evolution with their pests and pathogens. They require minimum inputs of labour or management. It has been verified that some of them are often superior in taste and/or nutritional quality to the introduced varieties (Opole 1993). Properly used, the genetic resource base could lessen Kenya's dependence on food aid and make its mark on the country's economy through increased exports. There are many factors that have contributed to loss of genetic diversity. They include colonialism and education.

Colonialism and Loss of Diversity

The status of biological diversity and genetic resources changed dramatically through colonialism. The introduction of exotic forest species brought on the clearing of massive areas of indigenous forests to grow uniform monocultures of forest plantations, mainly to produce timber for export to the colonial power. The first growing species (such as pine, eucalyptus and cyprus) had a uniform and narrow genetic base. This practice that is now well entrenched has led to total neglect of conservation and research on local species. Another reason for loss of genetic diversity has been the introduction of new crops, which undermine traditional diets and are already threatened by the erosion of ethnic culture and traditional. The western colonial condemnation of traditional food crops as inferior, primitive or marginal led to their abandonment particularly by so-called educated communities.

Education

Education in the current system of development has contributed to the gradual loss of indigenous knowledge about biological diversity by separating young girls from their mothers as they go to school. In school, curriculum subjects relating to agriculture and nutrition focus more on the methods of production and processing and on exotic food varieties. From kindergarten school, children are introduced to exotic foods as illustrated in the letters of the alphabet, where 'A' is for apple and 'C' is for Carrot. Most children in rural areas especially those from low potential areas will never see apples in their lives. At the primary and secondary level, most agricultural subjects promote exotic foods, while the university program focus on export production knowledge. Large multinationals use the media to promote their chemical products at the expense of traditional foods (Wellard 1993). On the other hand, education plays a major role in improving the status of women, the nutrition of their families and national food production. Female education brings significant social returns, with associated improvement to household health and nutrition, lower infant and child mortality and slower population growth. For agriculture, female education is crucial for higher productivity and increased implementation of environmental protection measures. Increasing agricultural production is therefore contingent not only on education but also on ensuring women equal access to extension, agricultural credit and other inputs and support services (FAO 1997).

But the greatest loss of genetic diversity is however, attributed to the impact of the green revolution, which seemingly increased food production with the introduction of the hybrid cultivars in food and cash crops. The Kenya National Food Policy of 1984 stated clearly that the objective of food crop research would be to continue the search for more productive varieties, with the emphasis of breeding programs being on continuous yield increases. Though absolute food yields may have risen initially when farmers used hybrid and other 'miracle' seeds, their genetic uniformity made them highly vulnerable to pests and diseases. In addition, they require high levels of costly chemical input such as fertilizers and pesticides, and farmers have to purchase seeds every season (Opole 1993).

Rocheleau (1991) botanical surveys of fruits and vegetables indicated that the diversity of plant crops is still high in Kenya. Men and women collected 66 fruit samples and 35 vegetables. Some indigenous vegetables and fruits (such as *Adansonia digitata* (baobab) and *Gynandropsis gynandra*) have proved to contain higher nutritional qualities than commonly introduced crops and vegetables (such as Kale and Cabbage) (Opole 1993). Women have been in the forefront in preserving biological diversity of fruits and vegetables. For example, Mwongela Muimi of Kitui has conserved more than 15 different species, which she has planted on her 18-hectare farm. Miumi claimed that the indigenous fruits do not need any special management and that diseases do not easily attack them. The diversity allowed her family to benefit throughout the year as the fruits ripened at different times. Thus women's role in seed selection and vegetative probagation is crucial not only in agricultural production but also in the conservation and enhancement of genetic resources (Rocheleau 1991). In Kathama - Machakos district of Kenya, women curbed famine and fodder shortages by turning to indigenous trees as reserve fodder source, in tree crops rather livestock as assets, and in diversity of wild fruits and vegetables and fruits (Shiva 1991). Wild foods were said to provide nutritious snacks, combat the effects of malnutrition and to serve as substitute for other foods. In a sample participatory study with women in Machakos, researchers found women relying on their prior knowledge of wild foods and had even acquired new knowledge about fodder plants (Rocheleau 1991). The researchers thus used women's knowledge on plants to set up an in-situ with possibilities of protecting and managing some of these plants. Women thus identified 118 indigenous or naturalized wild plant species used for medicine and 45 food for food (Rocheleau 1995). Out of these participants selected five fruit trees, three vegetables, and medicinal plants as candidates for conservation. As much as men and women's priorities varied, they knew many of the same places, classes of ecosystem, and plant associations. Whereas men's widely shared knowledge of local plants had been developed in range land food and fodder, their out-migration, sedentarization and formal schooling had militated against the transmission of this gendered science and practice to the young (Rocheleau 1995). Moreover, men's out-migration had removed adult men as tutors and created a labor shortage and double workload for women, leaving little time for traditional education in multi generational groups of either sex (Rocheleau 1995). The above illustration shows that women's work and knowledge is particularly relevant to these linkages through which ecological stability and sustainability is maintained. Women's labour through the collection of fodder, fuel, and minor forest products is crucial in enabling the resource flow necessary to enable the economy running in a sustainable way. The *Ober* tree, for example, provides wood for timber and fuel, leaves for covering ripening bananas and for the children to play with and the bark can be cooked up to make for children's ailments. Vegetables have multiple uses too. For example, 'spider weed' (*Gynadropis gynadra*), make a nutritious vegetable used for treating protein and vegetables and vitamin deficiency extract are used to extracts are used to relieve aching eyes Opole (1993). The production of indigenous vegetables and fruits and fruits rests solely on the immense time-tested knowledge power-base of women in agronomy, nutrition and post-harvest practices.

Displacement of Women in Biodiversity Management

Evidence from Kenya reveals that the shift from subsistence to commercial agriculture through the introduction of cash crops and the market economy has led to a reduction in women's sphere of influence and an increasing dependence of women on men for extension services, purchase of seeds and handling of tools (Dankelman and Davidson 1988). The disappearance of indigenous forest has meant that women have to walk further to collect forest products, like a Haryan woman put it, 'Now I have to steal the grass for my buffalo and when the landlord catches me, he beats me'. Whereas local women used to able to list 118 species of trees and their use, the new forestry experts could name only 25 or less, which highlights the differences in knowledge of genetic resources between local inhabitants and external experts. Women's crucial role in agriculture is gradually diminished by the introduction of new agrotechnology and crop varieties, which are aimed at male farmers (Rocheleau 1995). The woman's role becomes more and more that of a laborer as she loses her control over production and access of resources. The fact that men actually owned most of the private land sets the stage for a gendered struggle for access to resource (Rocheleau 1995).

As the transition to cash cropping expands, women's activities become both burdensome and less socially valued. Marginalization continues where there is need for cash to meet family needs. In Cameroon, for example, men were given land, seeds and technical training to enable them to produce rice for sale. Women were expected to carry out their traditional agricultural tasks in the cash-crop rice fields as well as cultivating sorghum for their families (Dankelman and Davidson 1988). In Kenya, colonial initiatives to privatize land in the 1950s and the government of Kenya's move to create individual ownership of land in 1963 undermined women's right to land. The government accredited most productive land to white settlers whereas the more marginal land was designated as reserved for racial and ethnic groups. Men were registered as landowners with justification that it is customary for men to own land women do not.

The increase in yields that follow the use of fertilizers, pesticides, high-yield seed varieties and mechanization can mean more work for women. In Sierra Leone the introduction of tractors and modern ploughs resulted in a decrease of the working day for men in the rice culture, but women had to work 50% more to finish weeding and maintain the large fields (Richards 1996). In Kenya and Uganda, the wide use of pesticide and fungicides displaced women who did 85% weeding were now redundant (Dankelman and Davidson 1988). As food providers, women play a central role in the nutritional make of the family. This is similarly affected by the development of large monocultures producing crops for export at the expense of subsistence foods. Large agriculture also places impossible demands on women, who may have access to land but rarely to the capital or credit to invest in machinery, hybrid seeds or chemicals. The inputs required by Green Revolution agriculture are usually beyond their economic reach Shiva (1993). Similarly, agricultural extension failed to reach women. This is because teaching of non-middle class women is not even considered in many areas, women have not been part of the mainstream of educational activity anywhere in the developing world. Yet illiterate women, out of reach of extension workers, are especially vulnerable to the indiscreet use of dangerous chemicals.

Spraying of fields and local storage of unsafe chemicals are special hazards for the women, whose children also suffer when their mothers are poisoned during pregnancy (Sachs 1996).

The Case of Cassava

The marginalization of women through the introduction of a new technology is best illustrated by technological advancements in cassava in Africa. For women farmers, lack of credit denies them access to any technology. They cannot afford to buy tools, equipment and fertilizers to improve their farm output. Cassava is the most important food crop for over 500 million people in tropical regions. Because cassava tolerates drought and low soil fertility, it is a major food crop produced by small-scale farmers in marginal areas with poor soil conditions and unfavorable climate. In most regions of Africa women are the main producers of cassava, and are almost entirely responsible for its processing. Women usually intercrop cassava with maize and other crops. Even when it is grown alone there will be variations: bitter or sweet varieties, those that can be eaten fresh and those that need processing. In spite of the importance of cassava as a food crop, cassava has been overlooked to a large extent by modern agricultural technologies because of its negligible importance to the industrialized world and if it is given recognition the benefits accrued always go to men. For example, when mechanized graters were introduced in the 1960s in Nigeria, to help reduce cyanide content in cassava, women lacked the capital to buy the grating equipment, and so what was traditionally a woman's industry began to move into men's hands. Men owned the graters and hired female labour to operate them. Hence men controlled the means of production-land, raw materials and mechanized processor while women had only their labour to put on the market (Rodda 1993). These pro-male bias apply in all other spheres as scientific fields and engineering fields continue to remain heavily male dominated and are along way from recognizing or giving a balanced attention to women.

Biotechnology development and research do not reverse the above situation but exacerbates it. International Agricultural Research Centres such as Cassava Biotechnology Network (CBN), CIAT, IITA, pay explicit attention to women but for reasons of efficiency than promotion of women's autonomy. (CBN-Newsletter No.2 1993) stated that when the different roles and needs of men and women are considered and when both are included in the design and testing of solutions to their problems, the resulting technology is more appropriate and more rapidly adopted. The research on genetic improvement of cassava that concentrates on the reduction of the natural cyanide toxicity in cassava mentioned above is a doubtful research priority for women. CBN research in Tanzania found that women were interested in new processing methods to improve nutritional quality for home consumption, and to increase the properties of cassava flour in such a way that it could be used to bake products for sale on the market. Women did not mention *cyanogen* content as a major problem. They in fact appreciate the 'bitterness' as a natural repellent to insects, rats, monkeys and pigs. Therefore, they grow both bitter and sweet varieties on their farms. Research on genetically lowering cyanide levels in cassava is therefore not carried out to support women. It is rather to open up new markets for cassava for which the cassava as a safe product needs to be enhanced. Low *cyanogen* levels in cassava could benefit cassava starch factories, since they will reduce the environment pollution they usually cause. The development of cassava starch factories could trigger the development of large-scale market-oriented cassava production. This production will increase the control of men as happened with the other cash crops. In this scenario men will take over the production of cassava, cutting women's income from the sell of processed goods on the local market. Small-scale cassava production and with it women's knowledge of cassava cultivation and biodiversity will be further marginalised resulting in an undermining of women's autonomy (CBN/CIAT 1993).

Women have always experimented and improved processing methods of cassava. Many examples of women's innovation, local methods for technical improvements of cassava processing and the quality of the final products can be found in practice as well as in the literature. Knowledge developed by women would be a more sensible step to improvement of women's autonomy than expensive and risky advanced technologies such as genetic engineering. The control over modern biotechnology has continued to be concentrated in the hands of a few private companies and as a result research is being directed towards the interests of industrialized countries and large scale agriculture more than small-scale (female and male) of the south. Since the needs of women have usually been ignored in the past, they are likely to be adversely affected by advances in biotechnology. The case on cassava indicates that the application of modern biotechnology is likely to weaken women's autonomy. The replacement of local varieties with new, HYV, lead to resource scarcity in the farming system. The shift, for example, from local pulses to introduced soybean implies a shift from domestic to industrial food processing, displacing women from their local resources. Current agricultural research concentrates heavily on increasing the yield of only certain parts of the crop, often those which can be commercially marketed (Dankelman and Davidson 1988). For example, traditional *Adansonia digitata* (baobab) and *Gynandropsis gynandra* provide nutritional diet; the HYVs of these vegetables do not (George 1981). In most cases the HYVs are completely directed at men and at commercial interests (Shiva 1993). Dwarf varieties promoted by the Green Revolution reduce the straw available for fodder and fertilizer, which are essential components of women's sustainable agricultural systems (Shiva 1991). The increased fertilizer use that is required by HYVs has stimulated weed growth dramatically. Further increasing women's work burden. The replacement of millet and other coarse grains by vegetables for export not only reduces local food availability but also lowers the production of fodder. Shiva (1993) observes that, the replacement of local varieties and biological diversity leads to the loss of the source of food, fuel, fodder and minor and their families.

The increased vulnerability of the system makes women's position more uncertain. Women also loss control over management of natural resources, and they also lose their control over labour as a result of changing structures and the increases in their work burdens (Dankelman and Davidson 1988). Further, the desk-killing and deintellectualizing of women through ignorance of their contribution to management, knowledge and experience of the agro-ecosystem result in a loss of women's knowledge and intellectual integrity with regard to forestry, agriculture, plant genetic resources and animal husbandry. Women also lose their status and decision-making power in the social system, breaking down their sense of dignity, self-respect and self-determination (Shiva 1992).

The Case of Maize

Technological advancements in maize varieties illustrate marginalization of female farmers. Maize a staple food for many rural areas in Africa is generally raised by women. Researchers have improved corn production mainly to solve food problems of Eastern Africa but these researchers failed to recognize women as maize producers. Women typically intercrop maize with beans, cowpeas, beans, peanuts, pigeon peas, squash, yams, and cassava (Shiva 1993). However, western scientists viewed African women's cropping systems as inefficient and a barrier to adequate development. Efforts were made to remove women from farming through programs that grant land titles, credit to purchase fertilizers, pesticides, and seeds to men and trained them in this new technology (Sachs 1996). Development efforts involve the attempt to transfer these technologies to men by providing credits to them to purchase new products such as new seeds etc. Typically agricultural extension service targets information about new technology and agricultural practices at male farmers. Programs designed on these lines failed to increase maize production partly because these programs failed to see that improvement of maize production depended on women's participation through access to land, credit, capital and training (Dankelman and Davidson 1988). Research on maize weakened the autonomy of women because of focusing on varieties suitable for animal feed rather than for direct human consumption. These changes will likely have negative effects on women small producers and nutritional status of poorer families.

Similarly, plant geneticists and seed collectors have disregarded women's knowledge and the value of their seed store. Instead plant breeders emphasize qualities that bear little relation to those poor farmers need. Poor farmers, most of whom are women, select seeds based on their cross-crop effects, stability, multiple uses, and maturity dates. By contrast plant breeders emphasize specialized market qualities and quantity of grain. Some agricultural scientists have ignored the locally desirable traits. Women raise early maturing varieties in their gardens, because they provide food during the slack season and provide less susceptibility to insects and disease (Zweizel 1995).). Biotechnology is expected to reinforce and deepen these trends. Biotechnology not only break sustainable resource flow, but also the natural evolutionary and local breeding mechanisms will be annihilation of diversity and sustainability in nature and, as a direct consequence, of basic human needs and rights (Shiva 1992). To reverse these trends, there need for baseline studies on women's knowledge, experience, roles and position in managing the agro-ecosystems all over the world, aimed at improving women's access to and control over these resources and systems Zweizel 1995).

The knowledge and experience of generations permit women to have great flexibility in cropping practices. For example, the decline in soil fertility in many parts of Africa has caused women to shift their cropping from maize to cassava, though traditional cassava has less nutritional value than maize. Women's agricultural knowledge provides security for themselves and for others. As long as women still engage in seed selection the future survival of traditional crops is assured. Women are now at the mercy of the seed-supply systems. Over time, most of them have lost their traditional knowledge of seeds since they no longer select them after each harvest for the following year. Modern agricultural practices contribute to genetic erosion of crop varieties, as women become more dependent on the purchase of hybrid seeds. Women are aware that participating in the new agricultural technology threatens their only means of control over their livelihoods. In Tanzania, for example, when new hybrid maize, fertilizers and pesticide were introduced and allotted to men by the government the women neglected the new crops. Similarly, in Ghana rural women were reluctant to accept new hybrid seeds since the crop had an unpleasant taste, hard to prepare, less resistant to drought and insects, required different storage methods and depended on fertilizers which changed its taste. Such concerns by women are not considered by development professionals and if they do, then they regard them as irrational and unscientific (Dankelman and Davidson 1992).

As already mentioned in the previous chapters, major environmental problems accompany modern agriculture. They include degradation of land through soil erosion, fertility decline due to over use and poor production practices, and contamination of soil and water through use of chemical fertilizers and pesticides. These environmental problems may have far reaching implications for women. Loss of topsoil and fertility decline from agricultural practices creates major problems in many regions of the world. Large-scale highly mechanized agricultural systems put intense pressure on soil. Many of these agricultural methods that employ new technologies, such as the plow, that contribute to soil loss and declining soil quality are exactly those that have replaced women's agricultural methods. More than any other technology, cultivation causes soil erosion. The 1900s the use of tractors in the United States replaced women's and children's family labour. In African regions, where relying on hoe cultivation, development agencies and national governments introduced the plow to men. Agriculture extension services trained men to use the ox plows and drive tractors. Mechanical equipment other than hand tools for land preparation whether tractors or plows, was viewed as men's domain. Women's limited use of heavy equipment did not derive from their desire to protect the soil, but from the fact that men monopolized this equipment. These systems of production simultaneously marginalized women and damaged the soil (Sachs1996). In most parts of the world, the poorest suffer most from pesticide poisoning, resulting from having to live near agricultural fields and their lack of option concerning access to safe water and health care. In many regions of the world women supply water for their households, and the contamination of local water supplies adds hours to their day as they seek safe sources of water.

CHAPTER 7

SUMMARY AND CONCLUSION

In this study I described how the introduction of modern agriculture led to dramatic increases in agricultural productivity in the developing countries. I also described how instances of environmental degradation such as soil erosion and erosion of biodiversity accompanied these developments. I deduced that these modern approaches –the Green Revolution and biotechnology - have not been appropriate to the African environment. Because of the unique African environment, there is need for a different development package based on the local circumstances and resources and therefore we suggest that Africa move toward a self-sustaining, economically viable and socially acceptable agriculture. This means an understanding of traditional farming systems that may reveal important ecological clues for the development of alternative production and management. It is clear from our survey in the study that sustainable agriculture will need a combination of both traditional and modern scientific knowledge. It will also need structural and policy changes required to correct inequalities in the distribution of resources and the role played by governments. NGOs and donor organizations. Most NGOs working in Africa are often interested in indigenous knowledge systems and in local varieties of grains, especially in the face of genetic erosion. Most importantly they work with disadvantaged groups and communities. including women. tribal groups, and disabled farmers. Since Green Revolution technology and biotechnology seem to favor the rich farmers and ignore the poor and disadvantaged farmers, the sustainable approach to agriculture that is advocated by most NGOs is information-intensive instead of physical input intensive.

From this study I conclude that to manage environmental issues, the entire community and not just individual farmers must become involved in monitoring the conditions of natural resources. There is a need for a system that is decentralized and one that is based on bottom-up approach with facilitators that have people-centered skill in addition to their technical skills. However, a decentralized 'bottom-up' approach must be complimented by a strong 'top-down' approach. Rolling and Wagemakers (1998: 287) rightly point out" such sound agriculture cannot be expected from introducing different methods and technologies to farmers, but requires a transformation of the entire conventional agriculture to an equally complex but different system that is ecologically sound and sustainable".

Kenyan NGOs such as ICRAF, KENGO, CPK and the Green Belt Movement adopt ecologically sustainable agriculture by involving local people and their knowledge. These NGOs involve women in the training through participatory rural appraisal methodology, and in so doing, raise awareness at a wider institutional level. This village-level participatory approach is modeled on existing local institutions, which use the village as the basis of social organization. The use of a participatory approach strengthens local initiative by backing the changes and innovations that farmers are already making instead of imposing completely new technological packages which do not take into consideration their resource constraints (Juma 1989, Opole 1993, and Wellard 1994). Using a bottom-up approach these NGOs pioneer in developing education material on tree production and management. They equate the use of local knowledge to sustainable development in agriculture and remind farmers of environmental damage that can result on the use of modern technologies. As Arum (1993; 147) points out, KENGO's efforts are "directed to activities that have positive impact on the rural needs of resource management and environmental conservation".

As noted above, sustainable agricultural growth in Africa can be achieved by both modern and traditional agricultural approaches. It is for this that reason that some within donor agencies such as the World Bank (1990) point out that Africa will need its own Green Revolution, a revolution of a different character from the Asian one. Whereas as described in this study, the Asian revolution was based on one or two dominant crops, grown mainly on soils whose fertility is renewed yearly by alluvial deposits. African circumstances are different. First, most soils present problems of one kind or another. For example, the dry areas are dominated by sandy soils that are poor at holding water and nutrients. Much of the humid lowlands have acid soils with aluminum toxicity that damages plants. Where soils are fertile like in East African highlands, the slopes increase erosion, or where the soils are alluvial and clay, the risks of water logging are high. Second, Africa's climate is also harzadous. Two thirds of the continent's land faces the risk of four or more droughts of two years or longer. Even in years of adequate rainfall, the rains can start late or finish early. The potential for irrigation to counteract this variability is much smaller than in Asia. Thus, the continent's diverse rainfall, soil and slope patterns interact to produce a bewildering diversity of microenvironments (Bernstein and Crow 1992). These special factors mean that Africa's Green Revolution should be quite distinctive. As already noted above many varieties produced by earlier breeding programs in Africa failed to spread. Although they did well on research stations, where soil management and water availability were good, they did not thrive under farmers' conditions. Varieties suitable for Africa must be widely tested on-farm to make sure they perform at least as well as farmers' own varieties under conditions of poor soils, poor management and low fertilization. Varieties that provide higher yields with no additional inputs will be readily adopted (World Bank 1990). Since a Green Revolution for Africa will not be static, there is a need to continually improve and adapt varieties and techniques suited to local and economic conditions. This means that research and extension will be crucial in this task. The farming systems research proved costly and time consuming and could not cover the vast diversity of tribes and ecology of African countries. An effective research system therefore will allow farmers themselves to serve as frontline researchers, adopting research results to their own unique complex of circumstances. The kind of training and visit system of extension work as developed in World Bank projects in Asia could not be applied in Africa. Experience from Kenya, Cote d'Ivoire, and Burkina Faso show that a distinctive approach is needed for Africa. An approach where extension farmers work with farmers groups to discuss their problems or constraints, practices and ways to improve them. Instead of an improved 'package' of seeds, and fertilizers, extension workers should survey and discover the most sought after local varieties for different conditions and help propagate them (World Bank 1990, p.67).

The approach taken by Sasakawa Global 2000 (SG 2000) encourages the diffusion of improved food crop technologies among small-scale farmers in Africa. In particular, improving productivity in major food crops grown by resource- poor farmers. Global 2000 has worked in the upper west region of Ghana, one of the driest areas but now recording high yields of Sorghum. The key to this success has been 'a simple technical package' of fertilizer, good seed and adequate plant population (Hadjor 1992). SG 2000 involves extension officers, researchers and thousands of small-scale farmers in the field test and demonstration programs. The project emphasize basic crop management such as improved varieties, moderate amounts of appropriate fertilizers and improved and timely cultural practices. Each farmer cooperative is provided with recommended inputs needed to grow a test plot, with the understanding that if she/he obtains substantial and profitable yields gain, the cost of inputs will be repaid either in cash or in kind. To illustrate the yield difference, the farmers plant a companion plot adjacent to the pilot plot employing her/his traditional technology. By employing a simple package of improved technology, cooperating farmers have obtained yields two-to-four times greater than previously obtained with their traditional technologies. With these production gains, farmer enthusiasm for the recommended technologies is very high and as great as that observed in India and Pakistan during the Green Revolution of the 1960s (World Bank 1991). Despite challenges to build a firm base for sustained adoption of yield-increasing technologies in Sub-Sahara Africa, the SG 2000 program demonstrate that improved food crops production technologies developed by national and international agricultural research organizations are appropriate for use by small-scale farmers. And despite the eager participation of thousands of small-scale farmers in the SG 2000 programs, the appropriateness of promoting the seed-fertilizer technologies remains controversial for most agricultural development specialists (World Bank 1991).

Sustainable Development Policy Needs

From the SG2000 experience I conclude that that alternative economic theories relevant for Africa will have to reflect the diversity that already occurs within it. Conventional theories tend to underrate the significance of diversity and promote uniformity. For development to occur in Africa, social systems need a measure of diversity, autonomy and the capacity to undertake experiment. This can be done through community groups, which in some African countries is already in progress. For example. Kenya has already started to decentralize its planning process (Juma 1989). This study is of the view that some features of social organization in Africa such as decentralized community life may lead to alternative technologies that are amenable to popular control. If this is done, the power of the state may be reduced but it may in the long-run lead to rapid changes particularly in the application of science and technology because in most cases technological development is closely associated with institutional change. The conventional trend has been to replace traditional practices with modern science, often at high social costs, but in a sustainable approach to agriculture, the government can work with existing resource to encourage the transition from the modern system to a more sustainable agriculture (Roling and Wagemaker 1998 p.39). There would be need for communication between farmers, researchers and other local actors. These would allow policies to focus on enabling people and professionals to learn together so as to make the most of biological resources. The use of a sustainable livelihood approach by developing countries at this stage will be more appropriate because, as noted in previous chapters, people become an end to development and not a means to an end. Sustainable agriculture in this thesis is therefore not viewed as a set of practices to be fixed in time and space, rather it refers to the capacity of farmers to adapt and change as external and internal conditions change. The problem, however, in developing countries such as Kenya is that they continue to prescribe the practices that farmers should use rather than creating enabling conditions for farmers to use locally generated and adapted technologies. In addition, environmental policies continue to view the rural poor r and women in particular as mismanagers of natural resource. As a result give technical prescriptions obtained from controlled and uniform conditions, and applied widely with little or no regard for diverse local needs and conditions (Scoones and Thompson 1994.).

The battle over genetic resources as discussed in chapter 4 will not be won at international conferences or through international conventions but will depend largely on the ability of the African countries to strengthen their scientific and technological capacity. This can be by establishing an effective science and technology policy. An effective science and technology policy should lead to the enhancement of the capacity of the African countries to generate technologies. There is need for a collective negotiation as regards to the legal aspect of technology transfer, an issue that has recently become controversial as a result of recent changes in patent law especially in biological innovations. Science and technology policy should be an integral part of development strategies without assuming that African countries have consistent and uniform development strategies. For example, some countries in Africa have economic policies based on agricultural production while others emphasize industrial output. Therefore, science and technology programs should be undertaken with the understanding of the economic history of a specific country or region

(Juma 1989). In this study we have also pointed out in the introductory chapter that there is a link between sustainable development and resource ownership and we have clearly pointed out that without secure rights over resources, rural people cannot take along view on the sustainable use of these resources.

Failure to review historical developments of these countries have led to abstract application of certain policies on a uniform basis without considering the existing diversity. Policies that aim at using science and technology to reduce poverty and enhance equity such as Green Revolution and biotechnology will have to take into account the fact that majority of poor people have little influence over science and technology. As such, these programs should be different from the ones in operational. Efforts must therefore be made to make sure that the focus of technological innovation is relevant to the needs of the poor and of their participation in the process (Juma 1989). Apart from these efforts, there is also need for policy changes regarding education especially for women in rural areas.

Education

Most African countries treat science education as one of the optional subjects available to students. There is therefore a need for African countries to reform their educational systems to respond to the scientific and technical needs of economic changes. One way to make sure that the population is informed about biotechnology is to make biology or related subjects compulsory at all levels of the educational system. Currently, it is imperative that the public is informed on biotechnology, which has become a vital technology that may easily alter the course of human evolution. Kenya, for example, has already introduced an educational system that emphasizes the technical sciences and is likely to take advantage of some of the advances in biotechnology. These advances will take place only in a climate of policy reform and institutional organization. It has been mentioned here that the education system as it encourages science-oriented systems should be inclusive of local culture and the knowledge/technologies that has sustained these communities (Juma 1989) .

Technological projects in African countries as well as in industrialized countries tend to fail largely because of limitations in institutional organization. This will require collaboration between the scientific community, the private sector, policy makers and sections of the international community. This means that Kenya, for example, should move away from the wait-and-see policy and participate actively in the global search for biotechnology information and how they can reinvent their own local knowledge within biotechnology inventions. To supplement these policy requirements, Juma (1989) argue that it will be necessary to study the existing laws in order to understand the various ways in which they may hinder or promote the development of biotechnology. If some of the existing laws are obstacles to rapid industrialization then there is a need to review the laws and keep them in line with technological imperatives of rapid industrial change. Other possibilities for conserving genetic resources could be efforts to encourage schools in the country to set up botanical gardens in which local plants would be conserved. This would ensure the conservation of local material and will also help educate the students about the value of local plants. Similar activities could be taken by the churches most of which are already involved in the production of vegetables and other crops (Juma 1989, Opole 1993).

Women

Policy changes should prioritize the needs of women because the success of agricultural development especially in Africa depends on women and therefore they need to be involved in all stages of policy design, formulation and implementation. Zweizel 1995).strongly points out that the science and technology programs generally focus on the integration of women into science and technology activities. But in this program women are viewed as the recipients rather than generators of knowledge. The focus on giving women the necessary opportunities, technologies and the necessary management skills diverts attention away from existing skills, knowledge and concepts that have enabled these women identify problems, establish priorities, and work out solutions. Similarly, women's programs tend to focus on improving the status, access to resources, education, training and empowerment of women in relation to men but little attention is given to the value of women's knowledge in relation to identified problems. A change in the African science and technology will, therefore, require major shifts in policy towards the rural sectors, which in most cases rely on women as the main sources of economic productivity. This means the introduction of new technologies should be build on existing capacities and involve women right from the stage of technology design to operation. Only by allowing women to influence the design of agricultural technologies can productivity be increased without major dislocations in the economic system. To reverse this trend the following FAO (1997) strategies of increasing the number of female agents by recruiting them with access to training, resources and logistic support equal to men can be followed. I recommend an increase in the pool of women qualified to provide extension by promoting the teaching of science and technical subjects to females, targeting females for intakes to agricultural colleges and providing more facilities for them at such colleges. Extension services should be provided to women groups where it is more efficient than individual contact or where women indicate a preference for group extension. In Kenya, studies estimate that group extension can reach twice as many farmers as the same cost as individual extension. It is important to ensure that women receive agricultural information and that the message and recommendation are relevant to women's production and activities. Farm technology should be identified to make more appropriate for women. Collecting and analyzing gender-disagreggated data and using this information to plan and implement policies and intervention should identify women's agricultural needs. Science and technology research should be designed from the perspective of women in order to improve the overall conditions of women and generate sustainable development for the communities they constitute Zweizel 1995).

Genetic resources and Biotechnology

There is a need for African countries to formulate policies to reflect alternative ways of protecting resources because of limitations in current legislation. There is therefore a strong need to introduce legislation that would guarantee farmers' rights over local genetic resources as an incentive to conservation. Such arrangements will also ensure that local communities benefit from modern breeding techniques without losing control and access over their material. One way to ensure that genetic resource is not lost is to entrust their conservation into the hands of farmers. The farmers would not only become custodians of different types of genetic resources but they can also be incorporated into breeding programs that emphasize in situ conservation. However, most modern agricultural approaches in Africa discourage farmers from growing their indigenous varieties. As result, the genetic resource base is gradually being undermined. Generally, farmers need incentives to conserve the wide range of genetic diversity available to them for purposes of long-term national agricultural conservation and diversification. Some efforts to strengthen agricultural research in various African countries offer opportunities to formulate national programs on genetic resources that would go beyond the currently disjointed and inadequate activities. There is a need to establish national capability in personnel and equipment. The example of community based tree-planting illustrates clearly that a local project if given policy support could go a long way in supplementing government initiative. The program will also be building on local knowledge and resources (Juma 1989, Shiva 1991, and Kloppenburg 1991).

The introduction of new crops into Kenyan agriculture likely changed the productive sector of the country. Therefore the genetic resources collected in the last decade will lead to new products and processes with unpredictable impact on the country. As such there is need to formulate anticipatory policies not only based on the negative impact of these technologies but also a review of some of the potential benefits of this emerging technology. Kenya has an existing capacity in the biological and biochemical science that is sufficient to enable it to formulate a core biotechnology program. However, the first step for countries such as Kenya, is to identify their priorities depending on current and anticipated needs as well as the available capacity. Sociologists have shown that the identification of research priorities is usually influenced by the micro-politics of the research community and the dominant figures in particular disciplines (Juma 1989). Care should then be exercised to ensure that the process is as representative of the real conditions as possible. This, however, may be difficult because the existing institutions in Kenya have a tendency to gear their research efforts towards products for which large markets exist. Yet the main problem facing Kenya and other African countries relate to the provision of basic needs to communities with low levels of income. As pointed out earlier, therefore, Green Revolution and biotechnology research are likely to discriminate against the poor and to change this trend will require definite policy reorientation by government. This thesis, however, concludes that policy re-orientations should be geared towards the sustainable livelihood approach, which is more appropriate with research priorities that are people oriented. It allows rural people take control of the direction of their development and define their own terms the meaning of sustainability.

Future Prospects for Biotechnology in Africa

Alleviating the widespread food gap and attaining food security or food reliance and nutritional adequacy should be the highest priority for African countries. To achieve this the production, productivity and sustainability of food must greatly be enhanced through the generation, development and transfer of appropriate technologies. While the potential of currently available technology should be rationally harnessed, new emerging technologies such as biotechnology should be used in conjunction with local technologies and not substitute for them.

In view of the above, the African strategy for biotechnological development should include both provision of direct support for biotechnological research, technology assessment and transfer and the creation and fostering of a climate where biotechnology can benefit. This will depend on governmental and public awareness, political will, policies and programs that build national capabilities and develop regional and international cooperation. The training of personnel should be a high priority in Africa. Important areas that are required for a successful biotechnology program are microbiology, plant biology, zoology, cell biology, virology and molecular biology (Juma 1989). In most Sub-Sahara Africa, people trained in these areas are in very short supply. Very few universities offer training with adequate laboratory facilities in molecular biology and recombinant DNA technology. Those trying to offer such training are constrained by the lack of equipment and staff (Bialy 1993).

The potential effects of biotechnology development are not always positive. In the African context, the negative effect is the displacement of crops. African countries should be aware of such developments and diversify their products or increase quality and cost effectiveness of their products not only to maintain their international market share but also to enhance or open up new opportunities (Baily 1993). FAO and other concerned international systems should assist African countries in developing early warning systems whereby potential relative substitution effects could be monitored and strategic adjustments brought about in time to avert damage. Commodities such as banana plantations, cocoa, oil palm, roots and tubers, which are of socio-economic importance to Africa, should be a priority of biotechnology research agendas of countries in the region. International agencies and research centers should pay more attention to 'orphan' commodities (Komen 1993).

Most African countries with an interest in modern biotechnology are aware of the need to institute adequate biosafety provisions and establish appropriate intellectual property and to institute adequate biosafety provisions and establish appropriate intellectual property and patenting systems. The status of the issue of intellectual property rights in the region is still in a state of flux. Policy makers and biotechnologists and in the region, in conjunction with concerned international agencies, need to address this issue more explicitly. The current paths of research and development have led to concerns that the disparity in harnessing biotechnology for agriculture and economic development may increase between industrialized and developing countries. To redress these effects international organizations such as FAO work to ensure that the benefits of biotechnology are shared by people in the north and the south, in both large and small, rich and poor countries (FAO 1990). Biotechnology as illustrated in chapter 4, is a technique that is amenable to popular participation especially through decentralized production systems that allow it be open to local control. The experience of the Green Revolution has shown how easily the public can lose control of a technology that is meant to serve them.

Altieri (1995) observes that an understanding of traditional farming systems might reveal important ecological clues for the development of alternative production and management systems in both industrial and developing countries (see also Table 3 in the Appendix). The role of research will be to learn how to share innovations and insights between industrial and developing countries and to end the one-way transfer of technology from the industrial world to the third world. Altieri also points out that this exchange must be even, especially in the area of biotechnology, which depends greatly on the availability of crop genetic diversity, much of which is still preserved in traditional agro-ecosystems. Sustainable agricultural models, therefore, will have to combine elements of both traditional and modern scientific knowledge. Complementing the use of conventional varieties and inputs with traditional technologies will ensure an affordable and sustainable agricultural production. Adopting this approach for the developing countries will require structural changes mainly to correct inequalities in the distribution of resources; it will also require that governments recognize rural people's knowledge as a major natural resource. In a sustainable agricultural systems, selection will be based on the interaction of factors such as crop species, rotations, row spacing, soil nutrients and moisture, pests, harvesting and other agronomic procedures that accommodate the need to conserve energy and resources and protect environmental quality, public health, and equitable socioeconomic development. This approach must also contribute to rural development and social equality. For this to occur a political mechanism should encourage diversification of farm production and emphasize farmers' participation in the development process.

APPENDIX

Table 1: Traditional Pest Management Strategies used throughout Developing Countries.

Strategy	Practice
Cultural Practices	Intercropping Overplanting Crop rotation Mixing crop varieties Selective weeding Use of resistant varieties
Physical Control	Selective Prunning Burning vegetation Application of material (e.g., ash, smoke, and salt)
Religious/Ritual Practices	Addressing spirits or gods Placement of crosses in the field Prohibition of planting dates

Source: Altieri (1995, p.274).

Table 2: Plant Disease Management Practices of Traditional Farmers: Sustainability, External inputs Needed, and Labour Requirements.

Practice	Sustainable	External Inputs	Labour
Mulching	yes	low	low
Fallowing	yes	high	high
Multiple cropping	yes	low	low
Rotation	yes	low	low
Burning	yes	low	low
Planting in Raised beds	yes	high	high
Tillage	yes	low	low

Source: Altieri (1995, p.124).

Table 3: Comparison between Green Revolution and Traditional Technologies.

Characteristics	Green Revolution	Traditional
Crops Affected	Wheat, maize and rice	All Crops
Dominant Croppping System	Monoculture, Genetically Engineered	Polyculture, Genetically heterogenous
Environmental Impacts and Health	Medium to high-chemical pollution erosion, pesticide resistance, Health Risks-Pesticide residues in food	Low to medium (nutrients leaching from manure)
Crop Displaced	Traditional varieties and land races	None

Source: Altieri (1995, p.148).

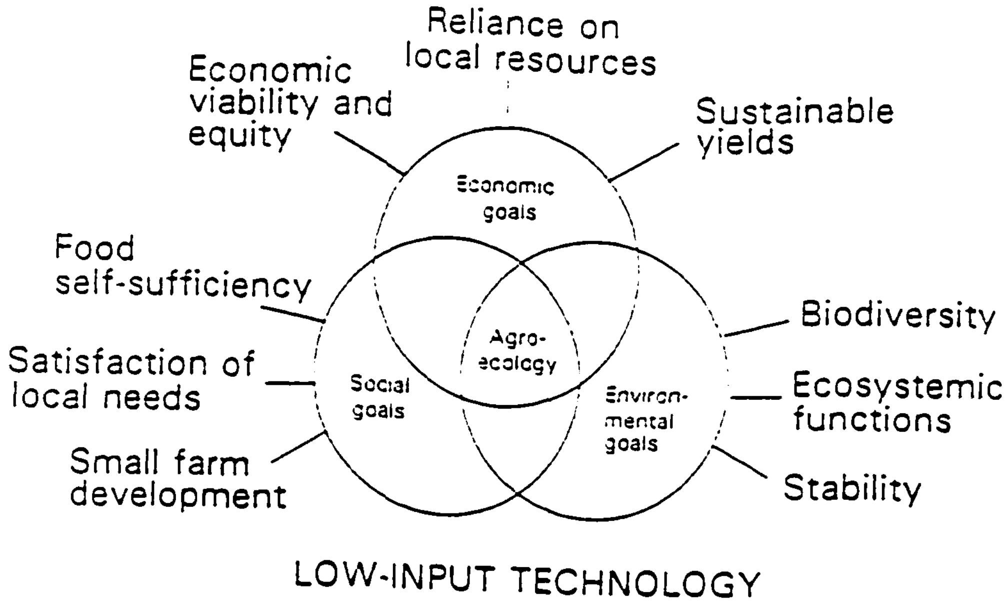

FIGURE 1 The role of agroecology in satisfying social, environmental, and economic goals in rural areas.

Altieri (1995: 176)

REFERENCES

Altieri. M. A (1995), Agroecology: The Science of Sustainable Agriculture. West View Press; Intermediate Technology Publications.

--------- (1991), Traditional Farming in Latin American. The Ecologists Vol.21.p.93-9

--------- (1987), "The Significance of Diversity in the Maintenance of the Sustainability of Traditional Ecosystems", IKEIA Newsletter Vol.3, No.2 p.3-7.

Anthrobus. P. (1996), "The on-going debates: what are the real issues? Of Perspective a Third World Feminists", in Liamzon et al (eds.), Towards Sustainable Livelihoods. Rome: Society for International Development.

Appleton. H., Fernandez M. E., Hill C. and Quiroz C. (1994), "Claiming and Using Indigenous Knowledge", in Harding.S (ed.), The Missing Link, pp 65-70. Intermediate Technology Publication. London.

Arum. G. (1993), "The Kenya Energy and Environmental Organization (1981-90)", in Wellard, Kate and Copestake, J.G (eds.), Non-Governmental Organizations and the State in Africa: Rethinking Roles in Sustainable Agricultural Development. Routledge. London, pp.145-158.

Baily. M. (1993), Bio/Afrique: An experiment in commercial biotechnology development in Africa. Biotechnology R &D trends: science policy for development. G.T. Tzotzo, Annals of the New York Academy of Sciences. Vol.7000, pp.261.

Baker. R. and Plucknett, D.L (1991), "Agricultural Biotechnology: a global perspective."

in B. R Baumgardt and M.A Martin, (eds.) Agricultural Biotechnology Issues and choices, pp.107-119. West Lafayette, Indiana, Purdue University.

Barnett, V., Payne, R., and Steiner, R. (1995), Agricultural Sustainability: Economic, Environmental and Statistical Considerations. John Wiley and Sons, Toronto, pp2-12.

Berlin, B. (1992), Ethnobiological Classification: Principles of Categorization of plants and Animals in traditional societies. Princeton, Princeton University Press.

Bernsterin, H. and Crow B. (1992), Rural Livelihoods: Crises and Responses Oxford University Press, pp.251-274.

Briggs, M. (1992), Basic Guide to Pesticides: Their Characteristics and Harzards, London And Washington, D.C.

Brohman, J. (1996), Popular Development: Rethinking the Theory and Practice in Development: Oxford Blackwell, pp. 324-52.

Brush, S.B (1996), "Is common Heritage Outmoded?" in Stephen, S.B. et al (eds.) Valuing Local Knowledge, vol. 1, pp.1-19: Washington, D.C. Island Press.

-------- (1992), "Farmers Rights and Genetic Conservation in Traditional Farming systems," World Development., vol.20, pp. 1617-1630.

Butorin, P. and Brian, W.(1990), Dictionary of Development: Third World Economy, Society and Environment. Vol.1, A-1, pp. 948-951.

Castro, P. A. (1991), "Indiginenous Kikuyu Agroforestry: A case Study of Kirinyaga, Kenya," Human Ecology, Vol. 19, No.1: Syracuse University: New York.

Chambers, R. (1993), Challenging the professions. Intermediate Technology Publication.

London, pp.65-67.

--------- (1987), Sustainable Rural Livelihoods: Crises and Responses. Oxford University Press; pp.51-174.

Chambers, R., Parcey, A. and thrupp, L. (1989), Farmer First: Farmer Innovation and Agricultural Research. Intermediate Technology publication, pp.14-23.

CGIAR (1991), A Review of the CGIAR Priorities and Strategies-Part 1, Rome, Italy. TAC Secretariat.

Clayton, E, S (1964), Agrarian Development in Peasant Economies: Some Lessons from Kenya. Maxwell, Publishers, London; pp. 107-110

Cleveland, D.A. and Murray. C S. (1997), "The World's Crop Genetic Resources and the Rights of Farmers," Current Anthropology, Vol. 38, No.4. Wenner-Gren Foundations; pp. 478-494.

Dankelman, I. and Davidson J. (1988), "Land: Women at the Centre of the Food Crises." In Sontheimer, S(ed) Women and the Environment. A reader crisis and Development in the Third World, pp.10-17 Earthscan Publishers.

Dommen,A.J (1988), Innovation in African agriculture. Westview press. Boulder and London. pp15-57

Cooper, D., Vllve R., and Hobberlink H. (1992), Growing Diversity: Genenetic Resource and Local Food Security. Intermediate Technology Publication.

Cox, C. (1991), "Glyphosate Fact Sheet," Journal of Pesticide Reform: Vol. II No.19.

Dove, M. R. (1996), "Center, Periphery and Biodiversity: A Paradox of Governance and a Developmental Challenge," in Stephen, S.B et al (eds.) Valuing Local Knowledge, pp.41-60: Washington, D.C. Island Press.

Evans, L. T. (1993), Crop Evolution, Adaptation, and Yield. Cambridge: Cambridge University Press.

FAO (1997), The State of food and Agriculture: The Agro-processing Industry and Economic Development, FAO, Rome, pp. 58-64.

------- (1990). Women in Agricultural Development. FAO's Plan of Action, FAO. Rome. pp. 14-20.

Feldman, S. and Welch, R, (1995), "Feminist Knowledge Claims, Local knowledge, and Gender Divisions of Agricultural Labor: Constructing a Successor Science." Rural Sociology 60 (1). Rural Sociological Society N.Y., pp23-43.

Fenandez M.E (1992). "The Social Organization of Production in Community-Based Agro-Pastoralism in the Andes", in C.M.McCorkle (ed.) Plants, Animals and People: Agropastoral Systems Research, Boulder: Westview, pp.99-108.

Fowler, G. (1994). Unnatural Selection: Technology, Politics, and Plant Evolution. Yverdon, Switzerland.

Fowler, G and Mooney, P. (1990). Shattering: Food, Politics and Loss of Genetic Diversity. Tucson University of Arizona Press.

George, S. (1981). How the Other Half Dies: Real Reasons for World Hunger. Allanheld, Osmon and Co. pp.113-132.

Glaeser, B. (1987). The Green Revolution Revisited. Allen and Unwin Publisher. London. pp. 1-9, 13-38.

Goldman, A.C (1991). "Tradition and Change in Postharvest Pest Management in Kenya."

Agriculture and Human Values, Vol.8, No.1/2. Intermediate Technology Publication.

Goodman, D. Sorj, B. and Wilkinson, J. (1987), From Farming to Biotechnology. A theory of Agro-Industrial Development. Basil Blackwell, pp.105-116: 133-139.

GRAIN (Genetic Resource Action International) (1994), Intellectual Property Rights for Whom?Barcelona.

Greaves, T. (1994), Intellectual Property Rights for Indigenous People: A Source Book Oklahoma: Society for the Applied Anthropology.

Gupta, A. (1994), "Compensating Local Communities for Conserving Biodiversity: Shall we Save the Goose that Laid the Golden Eggs so Long?" Indian Institute of Management Working Paper 1206.

Hadjor, K.F (1993), Dictionary of third World Terms; pp.200-204. London. Tauns and Co. Limited.

Hettne, J. (1990), Development Theory and the Three Worlds: New York:John Wiley and Sons.

Hoyt, E. (1988), Conserving the Wild Relatives of Crops: World Wide Fund for Nature; pp.20-21.

Jefferson, R.A. (1991), "Beyond Model Systems. New Strategies, Methods and Mechanism For Agricultural Research," Biotechnology Research and Development Trends in the Annals of the New York Research Academy of Science: Vol. 700, New York.

Jiggins, J. (1994), Changing the Boundaries: Women-Centered Perspectives on population and the Environment. Washington D.C.: Island Press.

Juma, C. (1989), The Gene Hunters, Biotechnology and the Scramble for Seeds, Zed books Ltd., London, pp.108-120.

Kang, B.T., Wilson, G. F., and Lawson, T.L. (1984), Alley Cropping A Stable Alternative to Shifting Cultivation. Ibadan, Nigeria: International Institute of Tropical Agriculture.

Keeler , M.and Turner, R. (1991), "Management of Transgenic Plants in the Environment," in Levin, M and Straus, H. (eds.) The Risk Assessment in Genetic Engineering,; pp.189-218. New York: McGraw-Hill Institute.

Kenney, M. and Buttel, F.H. (1984), Biotechnology: Prospects and Dilemmas for Third World Development, Paper presented at Conference on the Right to Food, Concordia University, Montreal, Canada.

Kimbrell, A (1998), "Why Biotechnology and High-Tech Agriculture cannot Feed the World," The Ecologists, Vol. 28, No. 5, pp.294-297, Cissbury House, Sussex-London.

Kloppenburg, J. jr. (1991), "Social theory and the de/reconstruction of agricultural science: Local Knowledge for an Alternative Agriculture," Rural Sociology, Vol. 56, pp.519-48.

Kloppenburg, J. jr. and Burrows, B. (1996), "Biotechnology to the Rescue? Twelve Reasons Why Biotechnology is Incompatible with Sustainable Agriculture," The Ecologist, Vol. 26, no. 2. (March/April), pp.61-67.

-------- (1988), First the Seed: The Political Economy of plant Biotechnology, New Haven Yale University Press.

Komen, J. and Persley, G. (1993), Agricultural Biotechnology in Developing Countries: Across-Country Review, ISNAR Research report No.2, The Hague, International service for National Agricultural Research.

Kothari, A. (1994), "Reviving Diversity in India's Agriculture,"Seedling, vol.11, no. 3, pp.6-13.

Lappe, C.(1998), World Hunger and the Myth of the green Revolution. Food First Books (2nd edition).

Macfarlane, R. (1990), "Biotechnology: Perils and Possibilities," Consumer Lifelines, Penag; Malayasia, Organization of Consumer Unions.

McCorkle, M.C. and McClure D.G. (1991), "Farmer Know-how and Communication for Technology Transfer: CTTA in Niger," in Warren, D.M (eds.) The Cultural Dimension of Development. Intermediate Technology Publications: London: pp.327-331.

Moock, J. (1992), Introduction in J. Moock and R. Rhoades (eds.) Diversity, Farmer Knowledge and Sustainability, pp.1-10. Ithaca: Cornell University Press.

Mooney, P. R. (1992), "Towards a Folk Revolution," in Cooper et al (eds.) Growing Diversity: Genetic resource and local Food Security. Intermediate Technology Publications. London; pp.125-137.

Mugabe, J. (1994), "Research on Biofertilizers: Kenya, Zimbabwe and Tanzania," Biotechnology and Development Monitor, no. 18, pp.9-10.

Netting, R., Stone, P., and Stone G.D (1989), "Kofyar Cash-Cropping: Choice and Change in Indigenous Agricultural Development," Human Ecology, Vol.17, No. 3, pp. 299

-317.

Opole, M. and Kiambi, K. (1992), "Promoting Traditional Trees and Food Plants in Kenya," in Cooper, D. et al (eds.) Growing Diversity: Genetic Resource and Local Food security; pp. 30-37. Intermediate Technology Publications.

Opole, M (1993), "Revalidating Women's Knowledge on Indigenous Vegetables": Implications for Policy, in Walter de Boef et al (eds.) Cultivating Local Knowledge. Intermediate Technology Publications; pp.57- 59.

OTA Office of Technology Assessment (1988), Enhancing Agriculture in Africa: A Role for United States Development Assistance. Washington D.C: United States Congress OTA-F-356.

Posey, D. A. (1994), "International Agreement and Intellectual Property Right Protection for Indigenous Peoples," in IPR for Indigenous Peoples: A source Book, Tom Greaves (ed), pp. 225-241; Oklahoma City: Society for Applied Anthropology.

Ramprasad, V. (1998), "Genetic Engineering Biotechnology and the Myth of Feeding the World," Biotechnology and Development Monitor, No.35, p.24.

Richards, P. (1985), Indigenous Agricultural Revolution. London: Hutchinson and co.

Richards, P. and Ruivenkamp, G. (1996), "New Tools for conviviality? Society and Biotechnology," in P. Descola and C. Palsson (eds.) Nature and Society: Anthropological Perspectives, Routledge: London.

Rislser, J. and Mellon, M. (1996), The Ecological Risks of Engineered Crops. Massachuttes Institute of technology (MIT) Press, pp. 27-48.

Rocheleau, D.E (1995), "Gender and Biodiversity: A feminists Political Ecology

Perspective," IDS Bulletin vol. 26, no. 1, pp.9-16.

------- (1991), "Gender, Ecology, and the Science of Survival: Stories and Lessons from Kenya," Agriculture and Human Values, vol. 8, nos. 1-2, pp. 156-165. Intermediate Technology Publications.

Rodda, A. (1993), Women and the Environment. Zed Books: London. P.10-17.

Rolling, N.G and Wagemaker, M.A.E. (1998), Facilitating Sustainable Agriculture: Participatory Learning and Adaptive Management in Times of Environmental Uncertainty. Cambridge University Press, pp283-307.

Rostow, W. W. (1960), The Stages of Economic Growth, Cambridge, U.K Cambridge University Press.

Ruttan, V.W. (1987), "Agricultural Research Policy and Development," FAO Research and Technology Paper, pp.35-44 FAO Rome 1987.

Pardy, P., Roseboom, J., and Beintema, J. (1995), Agriculture in Africa: Three Decades of Development. ISNAR Briefing Paper No. 19.

Sachs, C. (1996), Gendered fields: Rural Women, Agriculture, and Environment. Westview Press, Boulder, Colorado, pp.57-65.

Saito.A. (1994), "Raising the productivity of women farmers in sub-Sahara Africa," World Bank Discussion Paper No.230, Africa Technical Department Series. Washington, DC, World Bank.

Seers, D. (1968), " The Congruence of Marxism and other Neo-classical Doctrines." Discussion Paper, No. 136.Sussex, U.K: IDS August 1968.

Scones, I. and Thompson, J. (1994), Beyond Farmer First Farmer: Rural People's

Knowledge, Agricultural Research and Extension Practices Intermediate Technology Publications, pp.16-31.

Sharland, R.W. (1990), "Using Indigenous Knowledge in a Subsistence Society of Sudan." in Warren, D. M. (eds.) Cultural Dimensions of Development, p388-395. London: Intermediate Technology Publication.

Shiva, V. (1993), Monoculture of the Mind: Perspective on biodiversity and biotechnology, Penang: Third World Network.

-------- (1989), Staying Alive. London: Zed Books.

-------- (1991), The Violence of the Green Revolution: Third World Agriculture, Ecology and Politics. London: Zed Books

-------- and Dankelman, I. (1992), "Women and Biological diversity: Lessons from the Indian Himalaya," in Cooper, D. Vellve, R. and Hobbelink, H. (eds.) Growing Diversity: Genetic Resources and local food security, pp. 44-50. London. Intermediate Technology Publication.

Titilola, T. and Mazur, R. E (1992), "Social and Economic Dimensions of Local Knowledge Systems in African Sustainable Agriculture," Sociaologia Ruralis, Vol. XXXII pp. 264-286. VanGorcom, Assen: The Netherlands.

UNEP (1994), Farmers Rights and Rights of Similar Groups: The Rights of Indigenous and Local Communities Embodying Traditional Lifestyles. Article 8(j) of the Convention of Biological Diversity. Item 4.2.4 of the provincial agenda/ Nairobi.

-------- (1993), Agenda 21: Programme of Action for Sustainable Development. New York: United Nations Department of Public Information.

Soetomo, D (1992), "Sowing Community Seed Banks in Indonesia," in Cooper, D. Vellve, R. and Hobbelink, H. (eds.) Growing Diversity: Genetic Resources and local food security; pp. 30-37, Intermediate Technology Publications.

Strange, M. (1988), Family Farming: A New Economic Vision; Lincoln University of Nebraska Press. P.78.

Streinbrecher, R. A. and Mooney, P.R (1998), "The Terminator. Technology: The Thread to World Food Security". The Ecologists, Vol, 28, No. 5. Pp.276-279, Cissbury House, Sussex-London.

Streinbrecher, R. A. (1996) "From Green Revolution to Gene revolution: The Environmental Risks of Genetically Engineered Crops". The Ecologists, Vol. 26, No. 6. Pp.273-278, Cissbury House, Sussex-London.

Walgate, R. (1990), "Miracle or Menance," Biotechnology and the Third World, Panos Institute: London.

Warren, M.D. and Cashman, K. (1988), "Indigenous Knowledge for Sustainable Agriculture and Rural Development,"Gatekeeper Series No. SA10, International Institute for Environment and Development IIED, pp.3-10.

Wellard, K. (1992), "Linking local Knowledge Systems and Agricultural Research: the Role of NGOs," in de Boef, W. Amunor. K, Wellard. K. and Bebbington A.(eds.) Cultivating Knowledge: Genetic Diversity, Farmer Experimentation and Crop Research. London: Intermediate Technology Publications, pp.137-141.

Wellard, K. and Copestake, J.G. (1993), Non-Governmental Organizations and the State in Africa: Rethinking Roles in Sustainable Agricultural Development, Routledge:

London and NewYork, pp87-145.

World Bank (1990), The Long -Term Perspective Study of Sub-Sahara Africa. Economic and Sectoral Policy Issues, Washington D.C, vol. 2, pp. 48-73.

-------- (1991), Agricultural Issues in the 1990s: Proceedings of the Eleventh Agriculture Sector Symposium, in Garbus, L., Pritchard, A., and Knudsen, O. (eds.), Washington, D.C, pp7-23.

-------- (1975), Kenya: Into the Second Decade; report of a mission sent to Kenya by the World Bank. The John Hopkins University Press, Baltimore and London.p.447-492.

-------- (1963), The Economic Development of Kenya, The John Hopkins Press, Baltimore.

World Commission on Environment and Development (1987), Our Common Future, Oxford: New York, Oxford University Press.

Worede, M. (1992), "Ethiopia: A genebank working with farmers," in Cooper, D. Vellve, R. and Hobbelink, H. (eds.) Growing Diversity: Genetic Resources and local food security. London. Intermediate Technology Publication; pp. 79-91.

Yano, L. (1993), "Protection of Ethnobiological Knowledge of Indigenous People," UCLA Law Review: Vol.41: pp. 443-86.

Zweifel. H. (1995), "Modern Biotechnology in Agriculture: Impact on Women of the South," Biotechnology and Development Monitor, No.23, p.10-13. Web Version.

1. Norman Borlaug, director of the Division for Wheat Cultivation at Centro International de Mejoramiento de Maizy Trigo (CIMMYT) and Nobel Peace Prize winner was honored for having set in motion the Green Revolution and currently the president of Sasakawa Africa Assaciation. See Glaeser, B 1986, The Green Revolution Revisted, see also World Bank 1990, p7.

2. Biotechnology is a generic term for those technologies that use living organisms to modify existing life forms in order to generate new life forms.

3. Indigenous farmers or simply farmers refer to farmers who primarily follow traditional farming practices as opposed to modern industrial ones.

4. The views presented in this debate will provide an insight into the many other areas of conflict between indigenous and industrial viewpoints over the meaning of rights to global resources from global fisheries to medicinal plants to fresh water and clean water.

5. Biodervisty defined as not just a number of species that exist, but it is about indigenous way of life, of cultures that have established myriad of relationships, practical and spiritual, with ecological agricultural systems through the ages. Vandana Shiva sees biodeversity prospecting as the fast step towards accepting the dominant system of monoculture and monopolies, and thus towards accepting the destruction of diversity. According to Baumann et al (1997, p.127) the planet cannot afford to have biodervisty and traditional lifestyles that conserve biodeversity swallowed up as raw material for a globally-organized corporate culture which produces uniformity.

6.The term 'industrial agriculture' refer to agriculture based on inputs of agrochemicals, machinery, large-scale irrigation systems, and modern crop varieties (Todaro 1994)

7. Indigenous agriculture is agriculture that does not rely heavily on industrial inputs, is based to a great extent on local traditions, and uses locally adapted traditional crop varieties.

8. The current debate is however, between advocates of farmer's rights' in their folk varieties and the dominant world system, which vest intellectual property rights to crop genetic resources only in users of those resources for industrial agriculture. While indigenous people at individual and group level do not have a broad range of intellectual property rights in their folk varieties, they define and use them differently than does the industrial countries. A short historical background to the plant genetic resource will help explain the economic, political and socioeconomic perspectives of the debate and different schools of thought involved in the discussion.