

Intensive Subsistence Agriculture: Impacts, Challenges and Possible Interventions

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ABSTRACT

Subsistence farming is a form of production in which nearly all crops or livestock are raised to sustain the farm family, and rarely producing surpluses to sell for cash or store for later use. There are two major types of subsistence agriculture: primitive and intensive. Primitive subsistence farming, which includes shifting cultivation, slash and burn, and pastoral nomadic farming is mainly practiced in marginal areas. In contrast, intensive subsistence agriculture, which is the subject of this paper, is practiced in high potential arable land where land is scarce and the farmers have to maximize food production on relatively small fields. This type of farming exhibits a high degree of diversification (mixed crop-livestock systems), inter-cropping and limited use of modern technologies and purchased agricultural inputs. Intensive subsistence agriculture is widespread in many less developed countries where over 80% of their rural population is engaged in this type of farming. Intensive subsistence agriculture contributes substantially to economies of these countries and in alleviating food insecurity. It has high potential for increased growth if given the necessarily support. Despite this high dependence on subsistence agriculture, the farmers are faced with several challenges which unless addressed will continue to drag behind the economic development of these countries. This paper not only reviews the characteristics and impacts of intensive subsistence agriculture but also the challenges and possible interventions to these challenges.

Keywords: agricultural biotechnology, agroforestry, constraints, drip irrigation, environmental degradation, extension services, gender, globalization, HIV-Aids, irrigation, policies, soil fertility, wetlands

Abbreviations: FAO, Food Agricultural organization; GM, Genetically Modified; IFPRI, International Food Policy Research Institute; IFAD, International Fund for Agriculture Development; ISSAA, International Service for the Acquisition of Agri-biotech Applications; MDG, Millenium Development Goal

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INTRODUCTION

Subsistence agriculture is a form of agriculture in which nearly all the crops or livestock are raised to sustain the farm family (Clifton 1970). Although good weather occasionally allows the farmers to produce surplus, rarely do the farmers have enough surplus to sell for cash or store for later use. The farmers may sell a portion of their produce not because it is a surplus but because they are forced to meet some of their cash obligations or to meet a few family needs which they are unable to produce themselves. Because surpluses are rare, subsistence farming does not allow for generation and accumulation of capital and the farmers are not therefore endowed with financial resources to buy inputs for increasing productivity and hiring labor. The farmer therefore uses primitive farming tools and applies minimal or no inputs to increase crop yield and productivity. Intensive subsistence agriculture, the subject of this review, is mainly practiced in the developing countries of Africa, Latin America, Central and, East Europe and South East Asia (Devendra and Thomas 2002; Mathijs and Noev 2004; World Bank 2005). Although this type of agriculture occupies less than 10% of the world's land area, it supports over half of the world's population and contributes substantially to these countries' economies (Kostov and Lingard 2004). Intensive subsistence rice farming, for example, supports nearly three billion people, mostly in Southeast Asia, Southeast China and East India (Dawe and Dobermann 2000). In sub-Saharan Africa, subsistence agriculture contributes 8-50% of the Gross Domestic Product (GDP) and employs 40-85% of the rural population (Orkin and Njobe 2000; Kostov and Lingard 2004).

In this review, forms of subsistence agriculture and characteristics and impacts of intensive subsistence agriculture are discussed. The challenges associated with intensive subsistence agriculture and possible interventions have been discussed in greater depth. Cases where the interventions have been successful are briefly reviewed.

FORMS OF SUBSISTENCE FARMING

There are two major forms of subsistence agriculture, namely primitive and intensive subsistence agriculture.

Primitive subsistence agriculture

Primitive subsistence agriculture includes shifting cultivation, slash and burn, and pastoral nomadic farming. In shifting cultivation farmers typically cultivate a piece of land and abandon it when soil fertility declines. A considerable fallow period follows thereafter (Styger *et al.* 2007).

Slash and burn system consists of slashing and burning part of the forest vegetation and depending on population pressures and other factors, the cleared plot may be used for cultivation for between one to three years, and may then be left fallow while another plot will be cleared (Unai 2005; Styger *et al.* 2007). This system is only sustainable where land is abundant.

Pastoral nomadic agriculture is a type of agriculture where pastoralist communities move together with their livestock in search of pasture and water and do not have permanent shelter (Dixon *et al.* 2001a).

Given that modern technology is not used in primitive subsistence farming, the area of land that a farmer can cultivate each season is limited by available tools, crop type, manpower, the quality of the soil and the climatic conditions (Dixon *et al.* 2001b).

As a result of high population pressure, there is increasingly less land available for primitive subsistence cultivation and therefore the fallow periods are shortened and the plots are cultivated for more years making it unsustainable. With time therefore, primitive subsistence agriculture has evolved into intensive subsistence agriculture especially in high potential areas (Carloni 2001).

Intensive subsistence agriculture

Intensive subsistence agriculture is a type of agriculture in which the farmers maximize food production on relatively small fields. To maximize food production and to support the large populations on the small pieces of land, the farmers practice double and continuous cropping with no fallowing thus ensuring that no land is wasted (Dixon *et al.* 2001a, 2001b). The farmers also use minimal amounts of fertilizers (usually manure and occasionally sub-optimal amounts of inorganic fertilizers) to increase crop productivity (FAO 2005c). In addition, livestock are usually allowed to graze on land that is not suitable for crops (Carloni 2001; Dixon *et al.* 2001b; Unai 2005; World Bank 2005).

CHARACTERISTICS OF INTENSIVE SUBSISTENCE AGRICULTURE

Intensive subsistence agricultural systems are characterized by:

- 1. Extremely small farm size (0.25-10 acres) and seasonal reconfiguration of sub-parcels within fields due to socio-economic factors and land tenure systems (Orkin and Njobe 2000; Grigsby 2002)
- 2. A high degree of diversification (Fig. 1); mixed croplivestock systems and a large number of different types of annual and perennial crops are planted together (Smithson and Lenne 1996).
- 3. Low yields and high rates of crop failure (Fig. 2). Due to poor farm management and agricultural practices such as continuous cropping and lack of adequate and appropriate external inputs (fertilizers and quality seed), the land does not produce according to its potential and yields are therefore persistently low. Besides, there is a high rate of crop failure due to unfavourable climatic conditions and damage by pests and diseases. This is coupled with lack of irrigation facilities and other appropriate technologies that would mitigate against unreliable weather patterns (Ellis 2000).
- **4.** Limited use of purchased input. There is a limited use of purchased inputs (seeds, fertilizers, pesticides) in the crop production process. Sub-optimal amounts of fertilizers and pesticides are occasionally applied to marketed crops by some farmers but no inputs are applied to many subsistence (non-marketed) crops. Africa for example accounted for only 2% of world fertilizer consumption in 2003/04 while North America accounted for 15% (FAO 2005c). In sub Saharan Africa (excluding the Republic of South Africa), the average fertilizer use is only 10 kg ha⁻¹ (Wallace and Knausenberger 1997).



Fig. 1 Multiple vegetable cropping system in which kale (*Brassica ole-racea*) is cultivated together with maize (*Zea mays*) and cow pea (*Vig-na unguiculata*) in the suburbs of Kenya.



Fig. 2 Poorly performing maize crop in small holder farms in the dry parts of central Kenya.

- 5. High transportation and other transaction costs for purchased inputs and marketed outputs, and a lack of formal markets for some inputs and outputs. The transaction costs, for example includes the cost of searching for seller of the inputs, bargaining costs, screening the potential seller for trustworthiness and reliability and also searching for the best price (Key *et al.* 2000). All these components results to high transport and input prices.
- 6. Lack of production credit. Production credit is unavailable at all and when available it is only through informal sources. This is because rain-fed crop production is susceptible to periodic crop failures and therefore cannot guarantee repayment of credit if and when given.
- 7. High labour intensity. Intensive subsistence agriculture is characterized by high labour intensity with occasional hired labour. Women contribute 60-80% of the labour in intensive subsistence agriculture (FAO 1990; IFAD 2000).

IMPACTS OF INTENSIVE SUBSISTENCE AGRICULTURE

Loss of biodiversity

Increasing demand for agricultural land has inevitably resulted in competition for space with excessive pressure being exerted on natural resources. Indigenous forests are continuously being transformed into agricultural land. Loss of natural vegetation is known to trigger a series of changes most of which have major negative impacts on sustainability of the entire ecosystem (Feoli et al. 2002). Clearing of forests is usually marked by an initial slash and burn phase which gives way to intensive or semi-intensive cultivation depending on the demographic pressure in a given area. Apart from loss of biodiversity that is hosted in the stable forest ecosystems, nutrients are mobilized through volatilization, as a consequence of burning, or depleted through soil erosion and leaching. The situation is worsened by the poor soil and crop management practices that characterize subsistence farming that follows forest clearance (Altieri 1999; Wall 2004).

As the diversity of plants diminishes, the loss of biodiversity in the soil ecosystem, which is largely invisible to the naked eye, is triggered. Ecosystem functions such as breakdown of organic residues, nutrient cycling, plant pest and disease regulation, purification of water and detoxification of polluted sites are disrupted (Wall 2004). Studies have clearly demonstrated that agricultural practices, in general and intensive cultivation in particular, reduce biodiversity in soil ecosystems (Altieri 1999; Emmerling *et al.* 2001).

Although reliable estimates are yet to be worked out, it is widely accepted that the opportunity cost of clearing indigenous forests are enormous. The situation is further aggravated by the recognition that repair of what has been destroyed may take more than a lifetime, sometimes millions of years. Encouragingly, however, increasing concerns about the environment has stimulated some positive responses towards reforestation. Unfortunately, introduction of exotic plant species which are generally established in single species plantations has little value in restoring habitat, species and genetic diversity (Altieri 1999; Wall 2004).

Invasion of marginal and wetlands

Although most of subsistence agriculture is traditionally upland-based, increasing demand for land has shifted interest on every available space. Subsistence farmers are increa-singly cultivating marginal or wetlands areas that were not traditionally cultivated (Dixon et al. 2001b). The multidimensional roles of the wetlands as islands of diversity, reservoirs of excess water and sources of clean water and air have been sacrificed in favour of crop production (Bullock and Acreman 2003). For instance, indiscriminate drainage, in favour of bean production, has resulted in loss of more than 70% of wetlands in Rwanda. As reservoirs of beneficial organisms, wetlands have a regulatory function because they serve as an armoury of predators and parasitoids that control crop pests in the adjoining farms (Bullock and Acreman 2003). The safety haven provided by the wetlands for beneficial organisms escaping broad-spectrum pesticides in the neighbouring commercial and semi-commercial farms has been disrupted in the name of subsistence agriculture (Altieri 1999). The wetlands are largely regarded as communal resources for the common good of neighbouring communities. Overexploitation of wetland resources has exerted extreme pressure, causing enormous stress which has hastened their decline or demise (Bullock and Acreman 2003). Inevitably, conflicts have become a common feature given that communities have varying and diverse interests on the same resource (Dixon et al. 2001b).

Reduced water catchment areas

Intensive subsistence agriculture is expected to provide the farming communities with food throughout the year. This should happen against a unimodal or bimodal rainfall pattern, with only very few places receiving adequate precipitation throughout the year. In addition, precipitation in a given area depends to a very great extent on the natural vegetation cover. Increasing loss of forest cover results, therefore, in depletion of water sources and unreliable rainfall patterns. Consequently, intensive subsistence agriculture has evolved over the years to the extent where irrigation is becoming part of the strategies adopted by farmers as a remedy against erratic rainfall (FAO 2002; Lamm et al. 2006). Unfortunately, appropriate irrigation technologies, measures to reduce water wastage and policies to regulate its use are not well established (FAO 2002; Lamm et al. 2006). For instance, prolonged application of irrigation, without proper drainage, results in accumulation of salts which make the soil unsuitable for crop growth (FAO 2002). In addition, excessive uptake of water beyond the natural recharge or replenishment rate has interfered with water supply in some areas. Ultimately, water has become a non-renewable and scarce resource leading to valuable time being wasted in



Fig 3. Irrigation using sewage water in subsistence vegetable production systems in some parts of Kenya.

search of the commodity especially for domestic use (FAO 2002).

Scarcity of clean water and the cost of its pumping from far off sources has catalysed the use of waste water for irrigation in small-scale subsistence agriculture as depicted in **Fig. 3**. The practice is particularly widespread in urban and peri-urban areas. Health problems, especially with regard to spread of water-borne diseases have been raised but regulation of waste water usage seems to be a major challenge to the authorities concerned. It is evident that the practice is driven by very strong factors. Poverty and general lack of employment opportunities in the subsistence agricultural sectors are regarded as the main driving forces.

Soil nutrient depletion and infertility

Continuous cropping without application of organic or inorganic fertilizers has resulted in nutrient depletion from soils. The decline in soil fertility is attributed mainly to insufficient nutrient input compared to export through a number of pathways (FAO 2005c). Plant nutrients are removed from the soil in the form of harvested crops, through soil erosion, removal of crop residues for use as fuel or livestock feed, and leaching. Soil fertility decline has been rated as the major cause of diminishing productivity in subsistence agriculture (Bationo et al. 1998; Nandwa 2003). In addition, inappropriate methods are employed in collection, storage and application of the organic manures thus reducing their quality (Palm et al. 1997). Poor tillage practices that are characterized by excessive disturbance of the soil interferes with the biological processes that sustain soil fertility and hence the soil's ability to support plant growth. Inappropriate tillage practices lead to formation of hardpans and disrupt the soil structure thus reducing the water holding capacity of the soil (Craswell and Lefroy 2001).

Land degradation is a common feature in subsistence agriculture. It results mainly from practices that are adopted in preparation and management of the soil. Loss of soil organic matter is thought to be one of the main causes of land degradation (Moreira et al. 2006). Organic matter serves as a reserve for nutrients, improves water holding capacity, increases soil aggregation, increases the cation-exchange capacity (CEC), and sustains microbial activity, among other functions in the soil (Craswell and Lefroy 2001). It is estimated that land cultivation induces loss of soil organic carbon at the rate of up to 50% in temperate regions, over a period of about 50 years, compared to over 60% in the tropical regions over a period of only 5 years (Mann 1985; Resck 1998). The impact of organic matter loss is felt through a series of complex and interrelated processes resulting from reduced nutrient availability, water

holding capacity and microbial activity and, increased leaching, runoff, and soil acidity. The ultimate result of organic matter depletion is reduced efficiency of the soil as the main basis of crop production in subsistence agriculture.

Increased crop diseases and pests

Intensive crop production in nutrient depleted soils has been convincingly associated with increased severity of particularly soil-borne pests and diseases. For instance, evidence has been provided that damage by the banana weevil (*Cosmopolites sordidus*) is indirectly related to soil fertility (Oketch and Gold 1996). According to Byabagambi *et al.* (1999), damage caused by bean fly (*Ophomyia* sp.) was more serious in poor soils and especially under reduced rainfall conditions. Although the pest population increased with increase in nitrogen fertilizer application, its effect on yield was not significant and bean yield was higher in fertilized than in the unfertilized crop (Byabagambi *et al.* 1999). Crops grown in poor soils can hardly tolerate even the slightest damage by pests and diseases.

Subsistence agriculture relies largely on informal sources of seed with limited usage of certified seed (Devries and Toenniessen 2001). Farmers usually recycle seed from the previous season's crop or acquire it from neighbours, relatives or local food stores. This social seed network can be described as a classic example of how seed-borne pests and diseases can be disseminated across an entire village. Considering that some of the crop varieties are hybrids, loss of vigour usually means loss of tolerance to damage by harmful organisms. Use of infected planting materials reduces the chances of disease escape and enhances build-up of particularly soil-borne diseases. For instance, initial establishment of banana orchards in the subsistence sector is based on planting materials from neighbours while subsequent planting is mainly from the farmer's own orchard. With very few exceptions and depending on the area, banana suckers from old orchards are usually infested with plant parasitic nematodes, the banana weevil and other pests and pathogens which are effectively disseminated into the orchard where they initiate early infection of the crop resulting to high yield losses (Devries and Toenniessen 2001).

Increased rural – urban migration

The failure of subsistence agriculture to transform itself into a sustainable food and income-generating system has led to an ever increasing migration from the rural areas by particularly the youths and males. This has resulted in congestion in urban areas, with the attendant vices, and labour shortages in the rural areas especially during peak periods. The women who remain behind to turn the wheels of subsistence production are considerably overwhelmed by the wide range of responsibilities, including those that are traditionally shouldered by men (FAO 1990). The situation is further dimmed by the fact that the majority of the women who manage the production systems lack secure and legal authority over land due to discriminatory ownership rights (Feder and Noraaha 1989). Consequently, land productivity is reduced to levels where hunger and relief food are common phenomena to families that could sustain themselves with proper management (Ellis 2000). Prolonged absence of men from family settings has brought in social activities that result in spread of HIV/AIDS. Studies have clearly demonstrated that HIV/AIDS is one of the major setbacks to agricultural productivity and smooth passage of knowledge and farming know-how from generation to generation (Drimie 2002; Qamar 2003; FAO 2004). The aggregate of all these factors is a vicious circle of human suffering and hunger.

CHALLENGES OF INTENSIVE SUBSISTENCE AGRICULTURE

Low yields and high rate of crop failure

Perpetual low yields and high frequency of crop failure is a challenge that every subsistence farmer contends with globally (Evenson 2000). The low yields and high crop failure makes the farmers vulnerable to even the slightest drought and are major culprits of famine.

The challenge of low yields and high frequency of crop failure is aggravated by the ever growing demand for food due to increasing population. International Food Policy Research Institute (IFPRI), for example, projects that by 2020, food needs in developing countries will increase by 600 million tons which is equal to one- third of the current world food production (IFPRI 2001). The low yields and high crop failure is due to among other factors unreliable rainfall, pests and diseases, use of rudimentary farming technologies and lack of financial resource to engage skilled labour and extension services, to purchase modern farming implements, technologies and external inputs. Since subsistence agriculture is largely rainfed, unreliable rainfall, changing and unpredictable weather patterns occasioned by global warming greatly contributes to low yields and high crop failure in this type of farming system (Fig. 2). Much of Africa, for example, is subject to large rainfall variability of plus or minus 35%, implying poorly predictable droughts and floods (Carloni 2001). In addition, most developing countries have a lower water storage capacity than other regions (IFAD 1992). For instance, Ethiopia stores only 43 cubic meters per capita, compared to 6,150 in North America (Carloni 2001; Dixon et al. 2001a).

Continuous cropping with minimal or no application of external inputs to mitigate against loss of soil fertility and build – up of diseases and pests impacts heavily on crop yields and land productivity (Waceke *et al.* 2004; FAO 2005c; Arim *et al.* 2006). This is aggravated by monocropping, a common practice especially in staple food subsistence production systems. The yield losses due to diseases can be as high as 100% depending on the crop, the pathogen/pest involved and prevailing abiotic factors (Waceke *et al.* 2004; Arim *et al.* 2006).

Lack of finances by subsistence farmers limits their access to agricultural inputs such as fertilizers, pesticides and improved seeds that would serve to increase productivity of their farms and crop yields. It also limits access to extension services especially in countries where such services are not subsidized by the government. In addition, the inability to hire skilled or additional labor and to purchase farm implements that could increase the productivity of their farms and increase land under cultivation is also attributed to lack of financial resource (Key *et al.* 2000; IFAD 2001).

The declining financial support and investment in agriculture by the various governments in developing countries which rely heavily on external aid makes the situation even worse for the subsistence farmer. Agricultural external aid from bilateral and multi-lateral financial institutions and donors has sharply dropped since 1990 and according to IFAD (2001), real net aid disbursement to developing countries has fallen from 2.7% of the GDP in 1992 to 1.4 of their GDP by 1998.

Land shortage and poor land tenure system

Not all farmers have access to as much land as they can cultivate. Socioeconomic conditions prevent expansion of the farms and especially if inheritance traditions require that a plot is split among the owner's dependents upon his death. In this case the farm sizes and therefore their productivity steadily decrease as the population increases. In addition in the majority of cases, subsistence farmers do not have clear title to the land they own. The lack of secure land tenure therefore poses a constraint to sustainable subsistence agricultural development (Feder and Noraaha 1989; Grigsby 2002). Tenure security increases credit use as the title serves as a collateral, increases investment in fixed farm assets and minimizes incidences of land dispute (Feder and Noraaha 1989; Grigsby 2002).

Poor delivery of extension services

For a long time, the provision of extension services in developing countries has been the sole responsibility of the government. Over time, however, various government ministries, semi-governmental autonomous boards and private companies have created their own extension services, which work parallel to the main agricultural extension service (FAO 2005a). Lack of coordination among these various extension units has created confusion among the farmers as a result of duplication and/or conflicts of technical advice.

Poor technology dissemination systems, reduced funding or budgetary allocations, the poor linkages between research, extension and farmer and the fact that research does not focus on the actual needs of farmers has led to the slow adoption of the new technologies by farmers and has partly led to the collapse of extension services (FAO 2005b).

Poor/lack of infrastructure

Lack of adequate, affordable and reliable infrastructure as it relates to access roads, water, energy supply and telecommunications are a major constraint to agriculture and rural development as a whole in developing countries. Better transport facilities easily translate into better availability of agricultural services and products, access to financial institutions, access to markets and increased trade (Roller and Waverman 2001). Unfortunately, developing countries have poor road infrastructure. Africa, for example, has the lowest density of paved roads in the world and 14 of its countries are land locked (Jazairy et al.1992). Besides, less than half of Africa's population has access to safe drinking water and only about 5% have access to modern electricity with the remainder depending on traditional fuel, mainly wood (Kostov and Lingard 2004). On telecommunication, high disparities in access exist between urban and rural areas; the teledensity disparities have been estimated to be as high as 25:1 (Dymond et al. 2000). Though the availability of the cellular phone technology has to some extent changed the scenario for the subsistence farmers (Fig. 4), the cost of the technology still limits its access to many in the developing countries (Dymond et al. 2000; Roller and Waverman 2001).

Poor government policies

Government policies that are not supportive of subsistence farming have contributed to lack of incentives that would



Fig. 4 Semi-commercial small scale vegetable farmer using cellular telephony while on his farm in Githunguri; a major vegetable growing area for the Nairobi market in Kenya.

encourage the farmers to invest in subsistence agriculture. Where the policies exist, they are in most cases short term; addressing immediate needs of the farmers and favour the already financially endowed commercial farmers at the expense of the subsistent farmers. This has been partly because the subsistence farmers are perceived as passive entities when policies on agriculture are being formulated (Jazairy et al. 1992; FAO 2004). Recognizing that the farmer is the ultimate decision maker in adopting technologies and embracing policy and structural changes is key to active involvement of the subsistence farmers at all levels of policy formulation. Policies governing investments in rural development need to be revised to especially address the prob-lem of rural infrastructure. Water management policies need to be strengthened and farmers sensitized on the economic use of water (FAO 2002). Market oriented policy reforms are also required with the commitment of the various government to engage in agricultural economic activities. Policies on subsidies or credit for the purchase of external inputs and access to extension services need to be clearly formulated to enable the farmers increase production sustainably.

HIV/AIDS pandemic

The HIV/AIDS epidemic presents a major threat to food security and agricultural production of rural societies in many countries. Of the 36.1 million people who are infected world-wide, an overwhelming 95% are in developing countries (Drimie 2002; Qamar 2003). HIV/AIDS induces a downward spiral in the welfare of a family as health care expenses increase, productivity declines and family assets decrease as they are sold to care for the sick and pay for funeral expenses. The decrease in labour force leads to a reduction in the area under cultivation, the number of crops grown and therefore farm productivity (Drimie 2002; Qamar 2003). In the 10 most affected African countries, for example, the reduction in labour is between 10 to 26% (Dixon et al. 2001). HIV/AIDS has also led to the loss of local knowledge on farming know-how which is passed on from generation to generation. This directly affects subsistence farming as the survivors are left on their own to scavange for information. In Kenya, 58% of all staff deaths in the Ministry of Agriculture are caused by AIDS (Kiriro 2003). In sub-Saharan Africa up to 50% of agricultural extension staff time is lost through HIV/AIDS (Dixon *et al.* 2001b; Qamar 2003).

The most crucial short term action is to halt the spread of HIV/AIDS through prevention of new infections and appropriate management of the existing infections. There is also a need for safety nets to reinforce the efforts of rural communities to support AIDS orphans and for land tenure reform to prevent widows from losing access to, and control over land and household property when their husbands die (Qamar 2003; FAO 2004).

Women in subsistence agricultural production

Throughout the developing world, rural women engage in multiple productive and economic activities that are critical to the survival of their households. In Asia and many sub-Saharan Africa countries, for example, women produce 50-90 and 80-90% of domestic food, respectively (FAO 1990; Blackden and Chitra 1999; Evenson 2000). Globally, nearly 50% of all the farmers are women while in developing countries over 70% women of working age are engaged in agricultural work (Saito *et al.* 1994; Mathijs and Noev 2004). The extensive and increasing male migration to urban centers in search of formal employment further leaves subsistence farming solely to the women. At the same time, the proportion of woman-headed households continues to grow, reaching almost one third in some developing countries (Saito *et al.* 1994; Blackden and Chitra 1999).

Despite the significant roles they perform, women have limited access to financial, land and social assets; have fewer opportunities to improve their knowledge and skills; and less voice in public decision-making. Women, for example, own less than 2% of all land and receive only 5% of extension services worldwide (IFAD 2000, 2003). It is estimated that women in Africa receive less than 10% of all credit going to small farmers and a mere 1% of the total credit going to the agricultural sector (IFAD 2000, 2003). These persistent inequalities affect their ability to carry out their crucial roles effectively and result in considerable loss of productivity.

Effects of globalization on subsistence agriculture

Globalization presents both threats and opportunities for the agricultural sectors of developing countries. Globalization raises risks of marginalization for countries which, because of their poor resource endowment or lack of skills and infrastructure, remain uncompetitive in world markets. Globalization also brings with it the risk of "knock-on" effects on countries which are heavily dependent on the export of a narrow range of agricultural commodities. These "knock-on" effects are caused by unstable international financing systems and fluctuations in the performance of the world's major economies (Dixon *et al.* 2001a).

Given that agriculture is largely in the hands of subsistence farmers, is the economic mainstay of most developing countries and a main source of foreign exchange, reductions in barriers to trade expand the opportunities for raising the sector's output. The extent to which developing countries are able to take advantage of new market opportunities emerging from globalization ultimately depends on their competitiveness and their capacity to increase the production of goods which are in demand (World Bank 2005). This may require substantial investments in infrastructure, technology and communications aimed at reducing costs and speeding up transport. But it also calls for developing institutional capacities to set and enforce high standards and for training of farmers in the production of marketable products of a high standard (Dixon et al. 2001a, 2001b; IFPRI 2001; World Bank 2005).

POSSIBLE INTERVENTIONS

Introduction

The current mitigation tactic of providing food aid whenever there is famine in developing countries can only alleviate famine for a short time but does not solve the inherent problem of low subsistence production and can no longer be considered a long-term solution. Long-term strategies that maximize production per unit area (intensification) and diversification to higher value products on a sustainable basis, with minimal environmental degradation will play a key role in increasing productivity of the ever diminishing land sizes of subsistent farmers (Resck 1998; World Bank 2005). In addition, it will ensure adequate and sustainable food supplies and increase the profitability of subsistence farming. Some of these strategies which are discussed below include use of modern agricultural technologies, affordable irrigation schemes, improving extension delivery systems and increasing and facilitating the productivity of women. Other strategies that can be considered alongside those listed above include supporting the subsistence farmers to identify niche markets (for instance those for biologically grown produce) and establish viable market linkages; promoting small-scale agro-processing and value adding of farm products; encouraging farmer-based multiplication of quality seed; promoting self-sustaining, rural micro-finance systems to cater for farmers' demand for short-term credit and strengthening the capacity of farmer associations and support farmers' field schools where they exist (World Bank 2005).

Use of modern agricultural technologies

Many technologies, such as improved crop varieties, use of fertilizers and pesticides, better farm equipments, improved water-use efficiency, and, plant and animal husbandry have high potential in improving productivity and profitability of subsistence farming systems. Access to these conventional technologies is, however, still beyond the means of many subsistence farmers, as is evidenced by the very low levels of fertilizer utilization. Africa, for example, uses 19 kg of fertilizer ha⁻¹ per year, compared to 100 kg ha⁻¹ in East Asia and 230 kg ha⁻¹ in Western Europe (Wallace and Knausenberger 1997; Carloni 2001; FAO 2005c). Lack of access to these technologies is partly due to lack of input marketing and credit systems, high costs of transport (a function of poor roads and small volumes of trade) and lack of financial resources with which to buy the inputs. Because of this, other options of increasing yields and soil productivity without application of externally purchased inputs have been devised. Such options include agro-forestry whose use is gaining momentum especially in small scale production systems in developing countries (Palm et al. 1997; Franzel et al. 2002).

Agroforestry

Agroforestry is a type of land use where trees are combined with food crops and/or livestock on the same farm either simultaneously or sequentially with the aim of improving or maintaining the production in a sustainable manner (Steppler and Nair 1987; Franzel et al. 2002). Agroforestry is partly designed to improve soil fertility by replenishing soil nutrient pools, maximizing on-farm recycling of nutrients and reducing nutrient losses to the environment. This technology has successfully been adopted by subsistence farmers in Nepal and Kenya (Steppler and Nair 1987; Kiff and Pound 2001; Neupane and Thapa 2001). In Kenya, a majority of smallholder farmers have adopted two agroforestry systems; namely biomass transfer and improved fallows for soil fertility improvement and control of plant diseases and pests (Steppler and Nair 1987; Waceke et al. 2004; Arim et al. 2006).

Biomass transfer involves cutting and chopping of leaves and soft twigs of especially the wild sunflower *Ti-thonia diversifolia* before flowering, and then spreading them evenly over the surface and incorporating them into the soil as green manure (Mugendi *et al.* 2006). Farmers apply tithonia to high-value crops such as kales (*Brassica* sp.), french beans and tomatoes. Because the practice is labour intensive, farmers are currently growing tithonia along farm boundaries, and on contour ridges close to the fields, in order to reduce the time required to collect and carry the material into the field (Franzel *et al.* 2002; Mugendi *et al.* 2006).

Improved fallow, on the other hand, aims at restoring the soil fertility in especially maize production systems using fast growing leguminous plants mainly Crotalaria sp., Mucuna sp., Tephrosia vogelii and Sesbania sesban (Fig. 5). During the maize growing period, the leguminous species are sown after or during the second weeding and after harvesting the maize crop, the fast growing legumes are left to grow until the next maize-planting season. The legumes are then cut and left to dry for a few days before removing the woody stems and twigs (used for fuel) and incorporating the leaves into the soil by tillage before sowing maize. This allows continuous cultivation of maize for three years when the soil fertility and maize yield start to decline and the improved fallow is then repeated. Besides increasing soil nutrients and maize yields, the improved fallows have the advantage of suppressing the emerging weeds depending on the density and growth habit of the legume, suppressing nematode pests, supplying wood fuel, reducing witchweed (Striga spp.) infestation especially after a Sesbania fallow and allowing for continuous sustainable use of the farm (Steppler and Nair 1987; Waceke et al. 2004; Arim et al.



Fig. 5 Integrating *Mucuna pruriens*, a legume, for soil fertility and nematode pest management in maize production systems of the Central highlands of Kenya.

2006; Mugendi et al. 2006).

Using other leguminous plants such as *Callopogonium mucunoides* as fallow crops has been reported to not only improve soil nutrient levels but also reduce fallow periods in rice cropping systems in the savannah regions of northern Ghana. This new rice production technology has increased the area under rice cultivation by 45% and farm incomes by 34%. The farm incomes were not only reported to be higher but also more stable than with the traditional rice production systems namely bush fallows (Yiridoe *et al.* 2006).

Use of agricultural biotechnology

Broadly speaking, agricultural biotechnology consists of two components; cell and tissue culture and DNA technologies (Acquaah et al. 2006). Plant tissue culture, a relatively low-cost technology, aids crop improvement through; mass propagation of elite stock; production of pathogen-free materials; the selection and generation of somaclonal variants with desirable traits; the overcoming of reproductive barriers and the transfer of desirable traits from wild relatives to crops; the facilitation of gene transfers using plant protoplast fusions and anther culture to obtain homozygous lines in a breeding programme. DNA technology, on the other hand, involves genetic engineering which allows useful genes from any living organism to be transferred to crops or animals for improving their productivity. The transformed cells are regenerated into whole plants and evaluated for stable gene expression at acceptable levels in subsequent generations (Le 2001; Acquaah et al. 2006).

Plant tissue culture (micropropagation) is widely practiced in the production of disease-free and high quality planting material of the native clones of vegetatively propagated crop materials such as bananas, plantains, cassava, yams, sweet potato, sugarcane and many fruit trees and has a contributed considerably in increasing yields in subsistence farming systems in many developing countries (Graff *et al.* 2006). Micropropagation of banana, potatoes and sugarcane in Cuba and ornamental plants in India, for example, has contributed to the improved economic status of the subsistent farmer (ISAAA 1999). In China, micropropagation of virus-free sweet potato seed in Shandong resulted in an average yield increase of at least 30% (Fuglie *et al.* 2001). In Kenya, disease-free banana plantlets have greatly increased yields from 8-10 to 30-40 t h^{-1} (Anonymous 2000) among the small scale farmers. Unlike micropropagation, however, DNA technologies are yet to benefit subsistence farmers in these countries.

Agricultural biotechnology has high potential of effectively addressing hunger and poverty (MDG number 1) by stabilizing yields, providing nutrient enhanced (nutraceuticals) and better quality food, improving rural incomes, reducing negative environmental impacts and contributing to improved plant resistance to pests, diseases and tolerance to abiotic stresses (Goklany 2000; Acquaah et al. 2006; Graff et al. 2006). Yield increases of 10 to 35% for GM rice (Takahashi et al. 2001), enhanced vitamin A content in GM Golden Rice (Ye et al. 2000), reduced levels of cyanogen glycosides in GM cassava (Siritunga and Sayre 2003) and mycotoxins in Bt-cereals, enhanced tolerance to salinity, aluminum toxicity and low iron availability (Kobayashi et al. 1999; Takahashi et al. 2001), indicate that considerable gains have been made with genetic engineering and clearly shows the high potential of this technology in improving agricultural production (Graff et al. 2006).

Despite the benefits associated with the GM crops, their long-term environmental and health effects and socio-economic, ethics and legal issues need to be resolved, before uptake of the technology can be fully realized (Anderson 1994; Goklany 2000; Paarlberg 2000). In addition, the private sector commercial dominance of this technology, the high costs of patenting and cost of the associated heavy inputs such as water, fertilizers and additional labour, impair access by the subsistence farmers (Graff et al. 2006). Therefore, in order to fully realize the benefits of agricultural biotechnology in subsistence farming systems, a concerted effort need to be made by all parties; governments, development partners, the private firms and the farmers to ensure that the benefits of biotechnology are available to a broad spectrum of small scale farmers and involve crops which are important to subsistence farmers, and to traits such as biological nitrogen fixation that are of particular importance to low-income producers. Investments in higher education and intellectual property clearinghouse instituteons can greatly facilitate technology transfer (World Bank 2005; Graff et al. 2006).

Affordable irrigation techniques

Although most of the crops in subsistence agriculture are rainfed, irrigation can dramatically improve the outputs and will increasingly play a significant role in assuring global food security in future as the opportunities for extending the agricultural frontier diminish. Even low-input irrigation is more productive than high-input rainfed agriculture. Although irrigation covers only 17% of farmland globally, for example, it accounts for 40% of world food production (FAO 2002; World Bank 2005). The distribution of irrigated land, however, is unequal with South Asia, North Africa, Latin America and sub-Saharan Africa having 42, 31, 14 and 4% of the arable land irrigated, respectively (Dixon *et al.* 2001b; World Bank 2001; FAO 2002).

The subsistent farmers employ traditional irrigation techniques such as simple flooding, "Basin" and "Can" types of irrigation which are labour intensive, wasteful of water and can only irrigate a very small area of land where valuable crops are grown (Brouwer *et al.* 1988; FAO 2002). In flood irrigation, water is pumped or brought to the fields and is allowed to flow along the ground among the crops. In Basin-type of irrigation, soil moulds are made on all the four sides of small plots and the plots supplied with water through a small terrace made from nearby rivers (**Fig. 6A**) while Can irrigation involves the use of a watering can to manually irrigate the crop (**Fig. 6B**) (Brouwer *et al.* 1988).

Where public sector irrigation schemes exist such as the Gezira scheme in the Sudan, the Office du Niger in Mali, the Awash Valley scheme in Ethiopia, the Mwea Irrigation scheme in Kenya and the Jahaly/Pacharr scheme in the Gambia (Dixon et al. 2001b), the high cost of operation and maintenance coupled with the low output prices have made them unsustainable. Improving water use and productivity of existing schemes by building the capacity of farmers for greater participation in the scheme operation and by regular maintenance of the facilities are important considerations in making these schemes viable and sustainable. Where farmers have been allowed to manage the existing irrigation schemes or new farmer- managed or user group irrigation schemes have been established, the success rate has been high (IFAD 1992; FAO 2002). In the farmer managed schemes, the farmer groups operate and maintain the scheme through mobilization of local resources. These irrigation schemes have been successful in Turkey, Mexico (FÃO 2002), Niger, Mali, Tanzania and Guinea Bissau (IFAD 1992). The expansion of these schemes, however, depends on market-driven diversification of smallholder farming systems especially involving high-value horticulture crops (FAO 2002).

In addition to the formation of farmer- managed irrigation schemes, simple, affordable and water-efficient irrigation systems such as drip irrigation (Nakayama and Bucks 1986; Lamm *et al.* 2006; Karlberg *et al.* 2007) and hand or a treadle pump (Hyman 1995) have been developed and have served to increase efficiency and productivity at the subsistence farmer level, in many developing countries (IFAD 1992) with significant success.

Drip irrigation, also known as *trickle irrigation* or *micro irrigation* is an irrigation method that applies water slowly to the roots of plants, by depositing the water either on the soil surface or directly to the root zone, through a network of valves, pipes, tubing, and emitters (Nakayama and Bucks 1986; Karlberg et al. 2007). It is more widely used for row crop irrigation such as strawberries (Fig. 6C). Drip irrigation may also use micro-spray heads especially in tree and vine crops, which spray water in a small area, instead of emitters. Subsurface drip irrigation uses permanently or temporarily buried dripper line or drip tape. Because of the way the water is applied, the drip systems often allows for fertigation (application of fertilizers) and chemigation (application of pesticides) of the crops as the liquid fertilizers and pesticides are mixed with the irrigation water (Nakayama and Bucks 1986; Lamm et al. 2006). The drip system minimizes water usage, fertilizer, and labour costs, exhibits high water distribution efficiency and improves the quality of the crop. It also allows for dry-season cultivation of vegetables and fruits, increased crop production, an expansion of irrigated land and crop diversification and intensification (by up to 200-300%) (Lamm et al. 2006). In Cape Verde, for example, drip irrigation increased horticultural production from 5700 t in 1991 to 17,000 t in 1999 (198% increase) with a 0.2 ha plot providing the farmer with a monthly revenue of US\$ 1000 (FAO 2000; Karlberg et al. 2007).

A treadle pump, which is a foot operated water lifting device that can irrigate small plots of land and supply the requirements for several hundred square metres has been used widely especially in West Africa (Senegal), sub-Saharan Africa (Tanzania, Zambia, Kenya) and Asia to increase small scale farmers' income at low cost (FAO 2002). In Senegal, for example, the pump has enabled the vegetable peri-urban vegetable producers to generate annual net income gains of \$850 (Hyman et al. 1995). Diesel powered pumps are also used by semi-commercial subsistence peri-urban farmers (Fig. 6D). The difficulties often encountered by the subsistent farmer in marketing their crops after investing in irrigation equipment are major draw backs to expanding irrigation. Assisting farmers to identify and establish long term markets links will play a crucial role in the sustainability of irrigation systems (FAO 2002; Lamm et al. 2006).



Fig. 6 (A) Basin irrigation of kale (*Brassica oleracea*) in Athi River basin region in Kenya. (B) "Can" irrigation of cabbage in the central highlands of Kenya. (C) Drip irrigation of strawberries in a semi-commercial farm in the central high-lands of Kenya. (D) Semi-commercial subsistence farmer stores water in a small dam for irrigation and uses a diesel powered pump to irrigate the crops in the Athi River basin region of Kenya.



Given the importance of extension services to the subsistence farmer, measures must be put in place to enhance it and make it much more impactful. Innovative ways of delivering such services should be analyzed from a cost-benefit perspective and the necessary infrastructure put into place. The improved extension services have to be well-equipped (in terms of resources), efficient and armed with a broad technical mandate beyond technology transfer. Such services should promote well coordinated and established linkages between research, extension and farmers (FAO 2005a; World Bank 2005). This will require among others formulation of supportive policies; decentralizing decision-making to lower levels of relevant local organizations; institutionalization of systems for monitoring, evaluation and impact assessment; promotion of demand-driven services; investment in the empowerment and training of farmers to enable them to demand services effectively; promote gender equality and vulnerable groups' access to services; design structures for effective institutional cooperation; promote publicprivate partnerships and invest in rural infrastructure (FAO 2005a, 2005b). In some countries, like Uganda, the public extension services have been fully or partially privatized as

a measure to ensure sustainability (World Bank 2005).

Knowledge and information sharing is key to effective adoption of technologies. Effective systems of disseminating technologies need to be developed within the socioeconomic context of the subsistence farmer (FAO 2005a). More often the techniques used to communicate and disseminate the technologies have depended on infrastructure or resources which are not available in subsistence communities, besides the fact that the majority of the subsistence farmers are illiterate (FAO 2005a). Effective technology delivery systems include information packaging and good communication systems. The technologies, should be introduced to the farmers in non-technical language and the advantages of the technology must be demonstrated in a convincing manner with the costs and risks being clearly explained and discussed (FAO 2005a; World Bank 2005).

Raising productivity of women in subsistence agriculture

Given the important role that women play in subsistence agriculture, raising their productivity is crucial in ensuring sustainable rural development and increasing productivity in subsistence farming systems. This should involve the following: increasing women's access to resources, inclusion of women in decision making process and improving infrastructure in the rural areas (FAO 1990, 2001, 2004).

Increasing women's access to resources

This involves increasing women's access to, control over and benefit from basic assets such as land, water, natural resources, training and capital. This increases women's ability to influence the decisions affecting their lives and to perform their essential economic roles in the midst of increased rates of male migration. Having access to land gives the women security and status, and increases their influence at family and community levels (Saito et al. 1994; FAO 2004). Establishment of informal rural financial institutions whose services are tailor- made to rural women's needs is critical to increased access of credit by the rural women. IFAD (2000, 2003) reported that where women's rights to productive assets and services have been assured, achievements become more sustainable and household food security is usually enhanced. Inclusion of women in training programmes such as modern methods of crop cultivation, food production, labour-saving technologies, livestock and poultry management, small-scale industries, marketing and services boosts their productivity.

Involvement of women in decision making process

Women's participation in rural institutions and in decisionmaking process is an essential condition that brings about more effective and sustainable development processes. Facilitating the right of association and expression and building awareness of women's rights partly contributes to enhanced participation of women in community affairs (IFAD 2000, 2003; FAO 2004). Formation of self-help groups, savings and credit associations and production cooperatives, just to mention a few helps women to organize themselves around issues that affect their livelihoods and allows them to make practical improvements in their households and communities and to benefit from the solidarity of other members (Saito *et al.* 1994).

Improving basic infrastructure

Increased investments in basic rural infrastructure and services, particularly water, electricity, health and education increase the productivity of women. Limited access to these services places a special burden on rural women who are directly or indirectly responsible of providing them. Investment in rural roads, potable water, sanitation, schools, literacy classes and community centres will help bring these basic services closer to the communities and make them more affordable.

Fortunately many countries in Africa have introduced new legislation, institutions and programmes that will increase women's access to these services and productive resources. In Burkina Faso, for example, a national action plan has been prepared to increase women's access to agricultural services, to end discrimination in land allocation, and to create a fund for women's income generating activities (FAO 1990; Blacken and Chitra 1999).

CONCLUSION

The potential of subsistence agriculture to eradicate hunger and poverty and improve the well being of the rural communities in developing countries cannot be underestimated. The challenges the farmers face must, however, be addressed if this potential is to be realized. Meeting these challenges will require coordinated and concerted efforts by all the stakeholders, private and public sectors and the involvement of farmers at all levels of decision making. Active participation by the farmer involves participatory approaches to planning and implementation of programmes, building the capacity of the farmers and farmer organizations to influence policies. Upgrading existing basic rural infrastructures and developing new ones, increased investment in rural agriculture and, access to information and assured access to markets will be important supportive pillars for this great potential to be fully realized.

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