A Potential Nutritional and Household Economic Role for Integrated Agriculture-Aquaculture in Rural Africa: the Case of Ghana

ケネス・ラドル
Kenneth Ruddle

Small-scale freshwater aquaculture has been widely accepted by policymakers as an effective means of improving small-farm household nutrition and economies. However, despite a long and widespread history of failure in Africa, there has been little attempt to evaluate the potential of aquaculture - especially integrated systems of agriculture-aquaculture (IAA)- in rural development. An evaluation was conducted on the potential impact of the introduction of IAA into existing farming systems on household nutrition and cash incomes in the Deciduous and Rainforest, Transition and Guinea Savanna ecological zones of Ghana. The fish culture component is small-scale and based on extensive or semi-intensive pond systems. Farming systems were modeled with simple bioeconomic spreadsheets based on existing and actually measured information. The results demonstrate that the addition of a vegetable field and pond to modeled farming systems could directly improve household nutrition, and an indirect effect could be achieved through a considerable increase in household cash income. Based on an analysis of protein, carbohydrate, proximate minerals, and vitamin content of the food items, nutrient levels are marginally improved by the addition of a pond and vegetable field, whereas vitamin supply is significantly increased. In the 14 farming systems modeled, household cash incomes improved between 229 and 679%. However, most of this improvement is attributable to vegetable production, whereas cultured fish contributed only 2-4%, depending on pond size. The planned role of farm ponds in rural development should be expanded from that of mere "fish ponds" to exploit their fuller ecological potential.

Key Words : integrated systems, rural development, aquaculture

Introduction

There is an urgent need to increase both the productivity and profitability of agriculture, and especially of small-scale farming, in Africa south of the Sahara, where chronic food deficits have resulted largely from a rapid rate of population growth that exceeds the capacity of the small-scale farmer to meet increased food demands. In most parts of that region agricultural productivity per capita of consumer has declined and small-scale agriculture 'stagnant' and characterized by low average yields and low levels of modern inputs.

Given the precarious nutritional circumstances under which most Africans exist, coupled with the incidence of hunger and the occurrence of outright famine, there is a natural tendency to react with incautious optimism to any promising means of raising food production levels. This is particularly the case with a technology like freshwater pond aquaculture, which is new and not uncommonly strange to many organizations involved in Third World development. On the one hand, aquaculture is often promoted vigorously as a panacea by specialists with vested interests, but on the other, most members of such assistance organizations, versed mainly in agricultural development, are ill-equipped to assess either the merits of aquatic food production, the difficulty of sustaining aquaculture where there has been no continuous tradition of it, or the potential negative impact on environments and societies of inappropriate aquaculture development.

The principal policy objectives of freshwater pond aquaculture in Africa, are to:

- increase the production of fish as human food,
- improve the nutrition of resource-poor farm families, and
- improve the economic status of resource-poor farm families.

Most recent research and implementation programs (e.g., ALCOM, ICLARM) have aimed at both introducing small-scale pond aquaculture systems and/ or transforming existing extensive, small-scale pond aquaculture systems into semi-intensive systems via the integration of aquaculture with existing farming systems, whereby residues from other on-farm activities are utilized as pond feeds and/or fertilizers[1].

Aquaculture is no panacea for hunger or nutritional or economic deprivation. It is not a *replacement* technology; at best, it is a *complementary* or *supplementary* technology for producing food. As such, and like any other development, a balanced perspective is essential is considering its development. Above all, aquaculture must be seen in context. In particular, but not exclusively, it must be assessed in the context of:

- the demographic and socio-economic environment into which its introduction is proposed;
- the physical and biological environments into which its introduction is proposed; and
- national food supply and alternative sources of both animal and vegetable protein;

The overriding constraint to be addressed by development policy in Africa is alleviation of the all-pervasive poverty. Most households lack the money to buy their preferred types or the nutritionally beneficial quantities of food to supplement their subsistence product. This low to non-existent purchasing power, combined with the all-pervasive tradition of bartering for necessities, is a strong disincentive to private sector aquaculture development, for example. Thus if aquaculture development is to form part of national development policy it must be assisted at the village and household level.

As the history of past failures in Africa demonstrates, the development of sustainable aquaculture requires sound policy, well-conceived planning, and proper implementation via biotechnical and socio-economic research that works in tandem with a dedicated extension service. These are indispensable for ensuring successful and sustained development. Ill-conceived projects coupled with contradictory objectives were highlighted as long as two decades ago as a major source of prior failures in aquaculture development projects (FAO, 1975). For example, in one appraisal of the status of aquaculture in Africa it was observed that "most failures of aquaculture development programs in Africa so far can be explained by the lack of qualified technicians and of an adequate infrastructure, as well as by the absence of government policy specifically aimed at this form of development" (Coche, 1983).

The likely ability of most African countries south of the Sahara to satisfy domestic food demand from national sources is increasingly undermined by a rapid population growth under seriously deteriorating environmental conditions. The implications of this scenario for already impoverished and nutritionally vulnerable small-farm families gives rise to grave concern. In this paper I examine a possible role for integrated agriculture-aquaculture (IAA) in improving rural household nutrition and economies in Ghana. First the demographic situation and salient characteristics of resource-poor farm families are described in terms of land, labor, household budgets, and capital formation. The deteriorating environmental situation is then summarized and then the demand for and supply of principal food commodities and nutritional and health situation analyzed. Results of 13 small-sale farm models are presented to demonstrate the potential role of integrated IAA in enhancing both the nutritional and economic status of farm households. A brief projection of the potential of IAA is made at the national level.

The African Context for IAA Development

Socio-Economic Environments

The principal universal socio-economic contexts against which the introduction of aquaculture must be seen are a rapidly increasing human population together with the labor demand of and supply to existing agricultural systems, and the economies of households and other rural, small social groups. Other social and cultural factors are also of locally varied importance.

The physical and biological constraint introduced by aridity and proneness to drought, whether year-round or seasonal, has major agroeconomic repercussions, in that over much of Africa south of the Sahara small-scale agriculture is usually a risk-filled undertaking for the general welfare of households and rural communities. The all-pervasive risk is that whereas the rate of return to household labor invested in farming is invariably low (whether measured in terms of subsistence product or cash income), the opportunity cost of labor is high, and, if the rains fail, can be devastatingly so, when the incidence of hunger or even outright starvation becomes the unit of measure.

Throughout much of Africa south of the Sahara the low productivity of agricultural labor correlates closely with both the seasonal distribution of rainfall and its reliability (Woodhouse, 1989). Given the marked seasonality of rainfall in that region, the bulk of agricultural labor inputs are concentrated within a typically short 4 mo/yr growing season. Thus agricultural labor productivity is limited by the amount of indispensable tasks that can be performed during that limited time period. Risk is introduced by the physical ability of available labor to undertake the tasks - the incidence of illness and infirmity, age and gender, among other factors - and by both the capacity to hire labor and the availability of additional labor.

Risk-spreading techniques are customarily built into traditional farming systems as a hedge against such uncertainties. These include, for example, complex polyculture on individual farm plots, sequential planting of staple subsistence crops, and the spatial distribution of activities among several holdings with differing edaphic and micro-climatic characteristics. (Regardless of whether this latter characteristic is based on a sophisticated ethnoecological knowledge base [*i.e.*, conscious selection] or emanates from social organization [*e.g.*, kinship structure or inheritance patterns], in agroecological terms it is functionally the same.) Reciprocal labor, kinship obligations and communal mutual aid groups have traditionally served to smooth labor constraints.

Diversification of sources of household income has also been a traditional risk-spreading device. Thus, for example, small-scale farmers are not uncommonly either part-time or seasonal fishers; and beer-brewing is a frequent source of side-income for women. Opportunities to earn complementary, supplementary or totally alternative sources of income have been enhanced by urbanization and by the industrialization and commercialization of economies. Seasonal, long-term or permanent migration, particularly by younger, able-bodied males, for work in cities, mines or on commercial agricultural estates, is now commonplace throughout sub-Saharan Africa. The relative stability of such non-agricultural sources of income adds greatly to the opportunity cost of small-scale farming, and, ironically, exacerbates risk by destabilizing the age and gender balance of rural labor supply. This is off-set, however, where incomes earned in those other sectors are used to finance small-scale farming or to mitigate the risks inherent in adopting innovation (Laan, 1984).

A thorough understanding of the socio-cultural environmental context into which the introduction of small-scale aquaculture is proposed, and the tailoring of systems to fit that context, are absolutely essential prerequisites to any development project, since congruence or not with often complex socio-cultural variables guarantees either the success or failure of the introduction of any innovation, all other variables being equal.

Physical and Biological Environments

Africa is a continent of predominantly high elevation above sea level. Further, it is mainly an arid, semi-arid, or drought-prone continent. Together, these factors exert fundamental and severe constraints on the development of aquaculture. Since rates of fish growth correlate positively with temperature, much of the continent is sub-optimal for fish growth and limits the species that can be cultured. Obviously, where a reliable water supply is not available for at least most of the year, aquaculture is infeasible. Paradoxically, therefore, many areas best suited to aquaculture development are naturally fish-rich and are already exploited by freshwater capture fisheries. This is not to say that aquaculture development in such areas would be pointless; rather it highlights the need for a parallel development of distribution and marketing systems for fish products.

Further, and like any system of production, aquaculture is not free of impacts on the biological and physical environment. Freshwater pond aquaculture, for example, may disrupt hydrological systems by altering river flow rates and watertables, or facilitate the spread of waterborne diseases.

The success of aquaculture depends on the local availability of species suitable for culture. These will vary according to both the biological and physical parameters of the environment, as well as on such socio-cultural parameters as consumer preference. Indigenous species are preferable, but higher-yielding exotic breeds are commonly introduced. Exotics have the drawback that feral populations formed by escapes may threaten indigenous genetic resources, disrupt natural habitats or inadvertently introduce pathogens, predators and pests (Pullin, 1989).

National Food Demand and Supply and Alternative Sources of Protein

As an integral part of national development planning, it is also imperative to assess the potential role of aquaculture to satisfy nutritional requirements in terms of other sources of animal protein, as well as those of vegetable protein, lest effort and funds be squandered unnecessarily. Animal protein from sources other than fish may often be culturally preferred, as in Botswana, for example, where beef is the desired form; or marine fish might be preferred to that from freshwater. However, where the consumer preference is for fresh fish, aquaculture has a role to play, provided that the products of capture fisheries are neither cheaper nor more readily available. Consumer preference must therefore be ascertained. In terms of fish production alone, the economics and other benefits of aquaculture development must be compared with those of the marine and freshwater capture fisheries sectors.

Application to Ghana

The Demographic and Socio-Economic Context

The demographic situation in Ghana is alarming. The current population is an estimated 14.6 million, increasing at 2.6% per annum (ROG, 1989). At this rate the population would double in about 27 years. However, government policy aims to reduce the rate of increase to 2%/yr by the year 2000 (ROG-IRD, 1989). But the current 2.6% per year would give a population of about 18 million by 2000 and 32 million by 2020, and the rate 2% per year officially targeted from 2000 would give a population of 18 million in 2000 and 28.4 million in 2020.

A further important demographic characteristic of Ghana is its youthful age structure. Children (0-5 years-of-age) now comprise 20% of the total population, and those 0-15 years-of-age are almost half (47%) of the total. This has important implications for future population growth rates, employment generation, the provision of social services and physical infrastructure, and, of more immediate concern, for food supply.

Further, with a population of 32 million in the year 2020, the area of agricultural land per capita would decline from 1.95 ha (1988) to 0.43 ha (2020). The food security implications, at least at the household and community level, are obvious.

Some Characteristics of Resource-Poor Farms and Farm Families

Land

In Ghana, slightly over 80% of the farms are used either mainly or entirely for household subsistence purposes (MOA, 1988). Cash cropping is of greatest importance in the southern part of the country. Only in Western Region is cash cropping the predominant form, although it is of above average importance also in Western Region, Brong Ahafo, Eastern, and Greater Accra regions.

About 25% of Ghanaian farmers have just one farm (cultivated plot) on their total land holding. Further, 75% of all farmers have three farms or less, each of about 0.4 ha or less, giving a total holding size of about 1.2 ha, or less. 55% of the nation's farm holdings are less than 1.5 ha in area, and the median size is 1.44 ha (MOA, 1988).

The already deficient crop yield of such small farms (see below) is exacerbated by post-harvest food losses. An estimated 20% of harvest crops, primarily grains and legumes, is lost, mainly because of inadequate storage facilities (Sefa-Dedeh, 1981).

Labor

Traditional (*i.e.*, unmechanized) agriculture depends mainly on household labor, with 90% of farm labor being supplied by the farmer and his family (Ewusi *et al.*, 1983). Average rural households consist of 5 members (1970 census) (Ewusi *et al.*, 1983). Those in the North are larger: Northern Region 7.1 and Upper Region 6.5. There is an average of 3 children per farm family.

Females play a very large role in Ghanaian agriculture, and 70.3% (1970) of females farmers are engaged in food crop cultivation. They outnumber males in the cultivation of staples and vegetables.

A further problem is the ageing of the agricultural labor force. Since young males prefer alternative occupations, the male farm population is ageing. For example, whereas the total agricultural labor force increased by 22,714 persons during the period 1960-

1970 (the latest period for which such data are available), the main increase occurred in those above 45 years-of-age. In contrast absolute decreases occurred among younger males (Addae-Mensah, 1979).

In traditional agriculture all tasks are performed by manual labor, using mostly hand hoes and bush knives (cutlass). This is performed by family members supplemented for particular tasks during seasons of peak demand by hired, casual labor.

Apart from in female-headed households, males make a greater labor input to agriculture than do females. However, labor specialization by gender is evident only for land clearance, in which the heavy tasks of tree felling are performed by men.

At the community level, as exemplified in the Ashanti Region, there is a large over-supply of family labor (Fig. 1). However, depending on household composition and size, labor constraints could occur in January, March, April, and August, when land clearance makes major demands on supply.

Labor demands vary widely according to the crop assemblage cultivated. In the Ashanti Region they range from 69 persondays.ha^{-1} for a maize-cocoa combination to 537 persondays.ha^{-1} for a shallot-chili-pepper-eggplant-cocoyam combination. As a general rule, maize and pulses are the least labor-demanding crops, whereas vegetables and various admixtures of them with starchy staples have the highest labor demand.

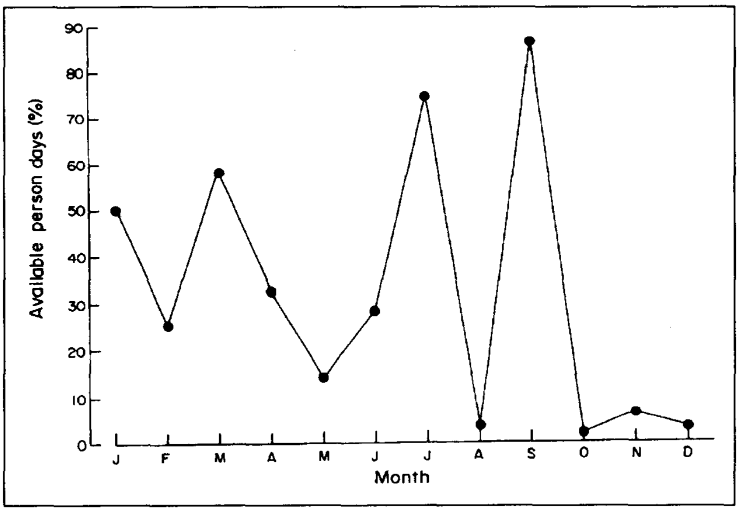

Fig.1.Monthly family labor absorption by farm activities in Sekyere District, Ashanti Region, as percentage of available person days.

Household Budgets and Capital Formation

Among resource-poor small-scale farmers in Ghana, the principal means of capital formation is through the sale of farm products (Fig. 2) and complementary foods, such as bushmeat and products from wild plants. This is often supplemented by off-farm sources of income, particularly during the agriculturally slack months. However, although unavoidable as a means of obtaining cash to buy such necessities as medicine and to pay various fees, it is important to note that the sale of farm products, and in particular staple products, exacerbates an already precarious nutritional situation in resource-poor households (see below).

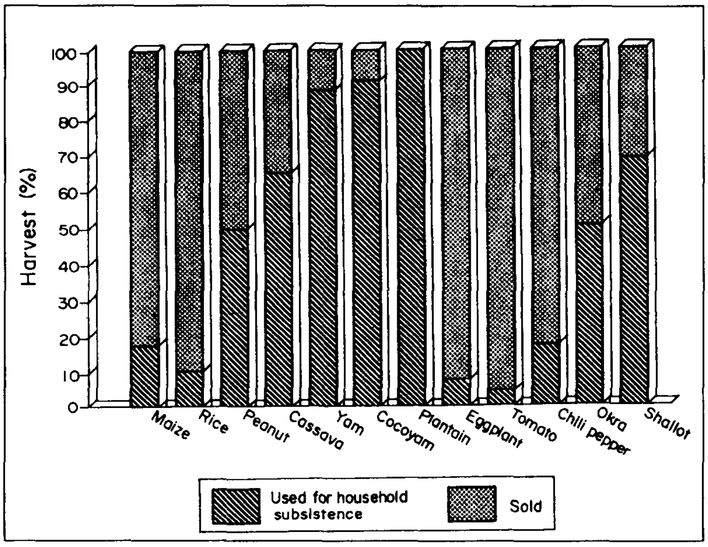

Fig.2.Use of farm crops for household subsistence and sale in Sekyere District, Ashanti Region by crop.

The data obtained through protracted field research at Adidwan Village, Ashanti Region, by Mensah (1987) have been used to exemplify household economics in this representative part of central Ghana.

(i) Gross Margin by Crop Enterprise

The combination of yam-chili-pepper-tomato yields the highest gross margin (USD 360), the highest return on labor inputs (USD 1.22.personday^{-1}), and the highest gross return per unit cultivated (USD 273.ha^{-1}). Shallot cultivation gives the lowest returns, with a gross margin of USD -73.0 , a return on labor of USD -0.30.personday^{-1}, and a return on area cultivated of USD -65. Maize, peanuts and maize-cassava all show negative rates of return. In general, vegetable and yam cultivation yield the highest gross margins and return to labor input, despite their high labor demand and therefore actual cost or opportunity cost.

(ii) Production Costs

The high cost of labor is the principal reason for the poor economic performance of cropping enterprises. Labor expenses are high for yam, peanut, vegetables, and shallot. This is exacerbated by the high cost of seed for shallot and yam.

(iii) Farm Cash Flows

At Adidwan Village, average net farm cash flows are positive at USD 21.5.farm^{-1} and USD 10.9.ha^{-1}. However, severe constraints are evident when cash flow is analyzed by month (Fig. 3). High expenditures for labor and planting inputs cause negative cash flows for half the year (January - June). Thereafter they turn positive for the remainder of the year, as crops are harvested and sold, and hired labor demands reduced.

(iv) Net Returns per Household

Net returns for most farmers in Adidwan Village are negative. Male-headed households have an average net return of USD 8.22 and those headed by females have an average of USD 1.52. Returns per hectare and per personday of labor are low and mostly negative.

(v) Net Farm Income

Average net farm income at Adidwan Village is USD 78.3. Those of male-headed households exceed those of female-headed households by USD 25.25. Return to household labor input (the major productive resource) averages USD 39.0. That in male-headed households exceeds that of females by USD 2.1.

(vi) Household Incomes and Expenditures

In Adidwan Village, for example, farm activities provide just over 98% of household income. The balance is derived from non-farm activities.

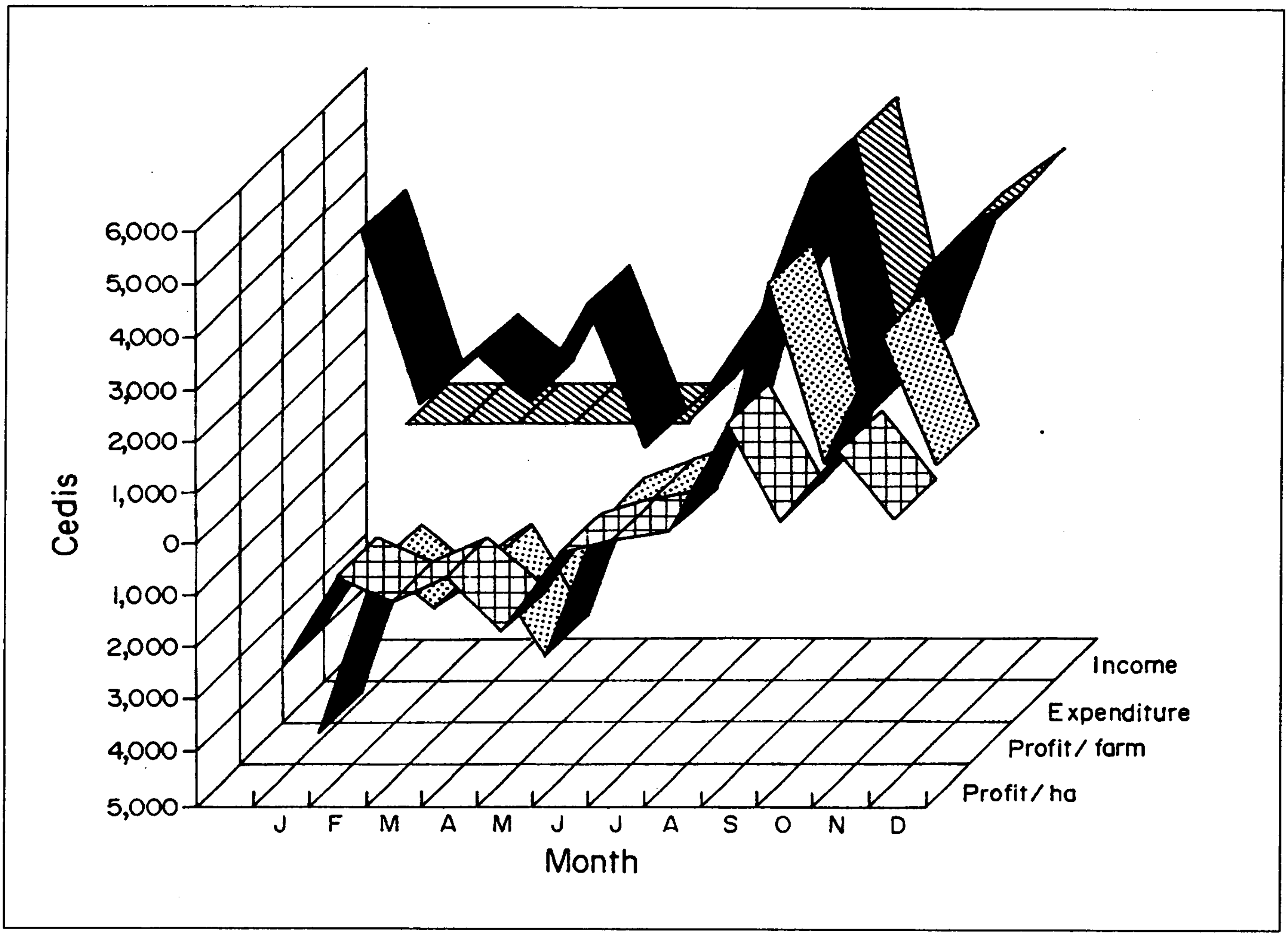

Fig.3.Monthly cash flows of small-scale farm households in Sekyere District, Ashanti Region.

Elsewhere, however, the situation may be considerably different, such as in areas where bushmeat provides a major source of farm household income. In Ghana, farmers who hunt as a sideline, depend on bushmeat for both food and cash income (Asibey, 1977). But reliable and recent data are not available to ascertain either levels of consumption or income. But a mid-1970s study of 80 farmers revealed that they sold 2,804 kg of bushmeat in 27 days and earned an average of USD 42.34 per capita and USD 1.56.caput^{-1}.d^{-1} (at the then prevailing exchange rate). One farmer had an average annual income for the period 1974-75 of USD 1,515 (Asibey, 1977). Such is the value of bushmeat that one farmer's income from the sale of bushmeat greatly exceeded the cash value of his maize crop (Asibey, 1980).

The sale of bushmeat is a critical source of capital for the resource-poor farmer: indeed, as Asibey (1977:47-48) observed, "without such support from hunting, most of the small-scale farmers in Ghana could not have carried out the farming of cocoa...". Given this major financing role of bushmeat, it is not surprising that nowadays many Ghanaian farmers "...no longer hunt for their domestic use alone but also largely for the urban and other population centers where bushmeat is relatively more expensive" (Asibey, 1974a). Such is the value of bushmeat that hunters prefer to sell their kill and purchase fish, which is much cheaper than bushmeat, for household consumption (Ntiamoa-Baidu, 1987). Informal discussions repeatedly reconfirmed this. This factor, together with the high urban demand for bushmeat is one major cause of the overexploitation of wild fauna (Ntiamoa-Baidu, 1987).

At Adidwan Village, food purchase comprises about 73% average household expenses. The principal non-food purchases are clothing (47%), funerals (19%), health costs (16%), schooling (7.9%). Expenditures exceed income by an average of USD 53.9. Thus there is little chance to accrue savings that could be used to capitalize new farm enterprises.

The Physical Environmental Factor

The demographic scenario described above will develop under increasingly difficult environmental conditions where naturally highly variable climatic and hydrological regimes, and their associated natural hazards, have been greatly exacerbated by anthropogenic factors.

Climate

Rainfall in Ghana is both highly seasonal and often unreliable. Southern Ghana enjoys a bi-modal rainfall distribution (*i.e.*, two seasonal peaks per annum). This sustains two crop seasons, and so permits a higher rate of crop production per unit area. Northern Ghana, in contrast, has a unimodal rainfall pattern; a single rainy season that severely constrains unirrigated crop production.

Further, total rainfall amounts and seasonality are unreliable. Severe droughts and floods are not uncommon, particularly in the Coastal and Northern Savanna belts.

Hydrological Conditions

Since Ghanaian agriculture is almost entirely rainfed, variability of rainfall is a major cause of crop failure. Water shortage in the dry season is an endemic problem that often becomes locally extremely serious in rural areas, where wells and bore holes are often dry for long periods. This means that women and children must often travel long distances each day to fetch manually the domestic water supply, a task that makes inordinate demands on their energy and daily time allocation, so exacerbating already precarious health conditions.

Soil Erosion

Deforestation for lumber, charcoal and fuelwood production and to create agricultural areas, reduced fallow periods in cultivation cycles, as well as poor soil management and conservation are leading to greatly accelerated soil erosion throughout Ghana (Anon, 1991). *Slight to moderate sheet erosion* affects 30-50% of all regions; *severe sheet erosion accompanied by gulley formation* is serious and widespread throughout Ghana, affecting more than 50% of the area in Western, Eastern, Ashanti, and Brong Ahafo regions; and *very severe sheet erosion accompanied by gulley formation* is even more widespread throughout Ghana, proportions of regions severely affected ranging from a "low" of 50% in Volta Region to a high of about 87% in Western Region. Desertification is of serious concern throughout Ghana.

Declining Soil Fertility

Soil fertility under systems of shifting cultivation, the main agricultural system in Ghana, was traditionally maintained by the use of a multi-year fallow period. But population pressure has now led to more continuous use of farmland, and fallow periods have been either shortened or eliminated. Such solutions as planted fallows, cover crops, mulching, alley cropping, and minimum tillage, are all labor intensive, and thus, because of expense, have not been widely adopted. (The cost of labor is a major constraint to agricultural development in Ghana.)

Thus inorganic fertilizers are used to maintain soil fertility. Without these supplementary nutrients, soil degradation is likely to become irreversible, crop yields will decline, and the human carrying capacity of the land will continue to decrease, although at an accelerating rate. But for now familiar reasons, the use of inorganic supplements is undesirable. Thus fertilization must be supplemented and hopefully replaced by organic materials.

In addition to the familiar ecological arguments against the use of inorganic fertilizers, is that their application in the amounts required to recover degraded soils is economically infeasible in Ghana. For example, just to replace the amount of nitrogen removed annually by staple food crops would require the annual application of the equivalent of 332,000 t of ammonium sulphate. And to provide the phosphorus would need some 116,000 t of superphosphate, or 330,000 t of 15:15:15 compound. In contrast, in 1989 the total fertilizer imports of Ghana amounted to a mere 45,000 t (FAO, 1989a).

Forest Destruction

Deforestation is a major problem throughout Ghana. Southern Ghana has now some 1.7 million ha of forests. But these are being degraded or destroyed at an annual rate of about 2% of their total area. At this rate by the year 2020 there will no longer be a forest industry in the country (FAO, 1991).

Charcoal burners are responsible for much forest destruction in the Transition Zone (FAO, 1991). In northern Ghana, especially in the Upper East Region, economically important trees formerly left in farmland have been felled to provide domestic fuelwood. In areas of high population density in the savanna zones, woodlands and park savanna are experiencing serious depletion, at a rate of about 20,000 $ha.y^{-1}$ (Friar, 1987).

Not only does this deplete and degrade timber resources, it also destroys the habitat for the fauna so important for providing the farmer with bushmeat, an important source of income (see above). It also destroys the source of complementary plant foodstuffs. On the other hand, when grasslands develop in formerly forested areas certain animals, like the grasscutter (*Thyronomys swinderianus*), a major item of bushmeat, are able to expand their range.

The principal social consequence of those environmental conditions is that since the direct annual cost of environmental degradation is estimated conservatively at 4% of the GDP of Ghana (about USD $67{,}200{,}000.y^{-1}$) for environmental reasons Ghana is foregoing annually 4% of the *potential* national economic output. Agriculture imposes the greatest single cost, at USD $46{,}080{,}000.y^{-1}$, or 69% of the total costs of environmental degradation (Convery and Tutu, 1990). In turn, this implies that present positive economic growth rates are not sustainable, because they are being maintained at the expense of future growth; *i.e.*, economic growth is based on undermining the biological and physical foundations of future productivity (Convery and Tutu, 1990; Anon., 1991).

The principal short-term impacts of this are:-

- an irreversible loss of productive land and thus an increased population pressure on remaining productive areas;
- a loss of soil fertility and thus declining crop yields, leading to direct and indirect (through price increases) hunger and nutritional deprivation among the poorer segments of society, and therefore increased health problems;
- a decease in household, community and national food security;
- a decrease in water supply;
- a decrease in fuelwood supply; and
- an increased expenditure for food, fuel and fertilizer imports, which, since they cannot be paid for by exports from a declining resource base, will require increased international assistance.

National Food Supply and Demand and Alternate Sources of Protein

Analysis of the range of yields of staple food crops for the period 1970-1986 demonstrates that none are achieving their theoretical potential yields (ROG, 1987) (Figs. 4 and 5). None of the yields of cereal crops achieve more than 35% of their potential productivity. Cassava also yields only at about 34% of its potential rate. Yam (at 58%) and cocoyam (at about 68%) come nearest to attaining potential yields.

At the national level, with the exception of cassava, for which the supply exceeds demand by 57%, the supply of all staple crops falls far short of demand: yam (133%), maize (131%), rice (59%), and millet and

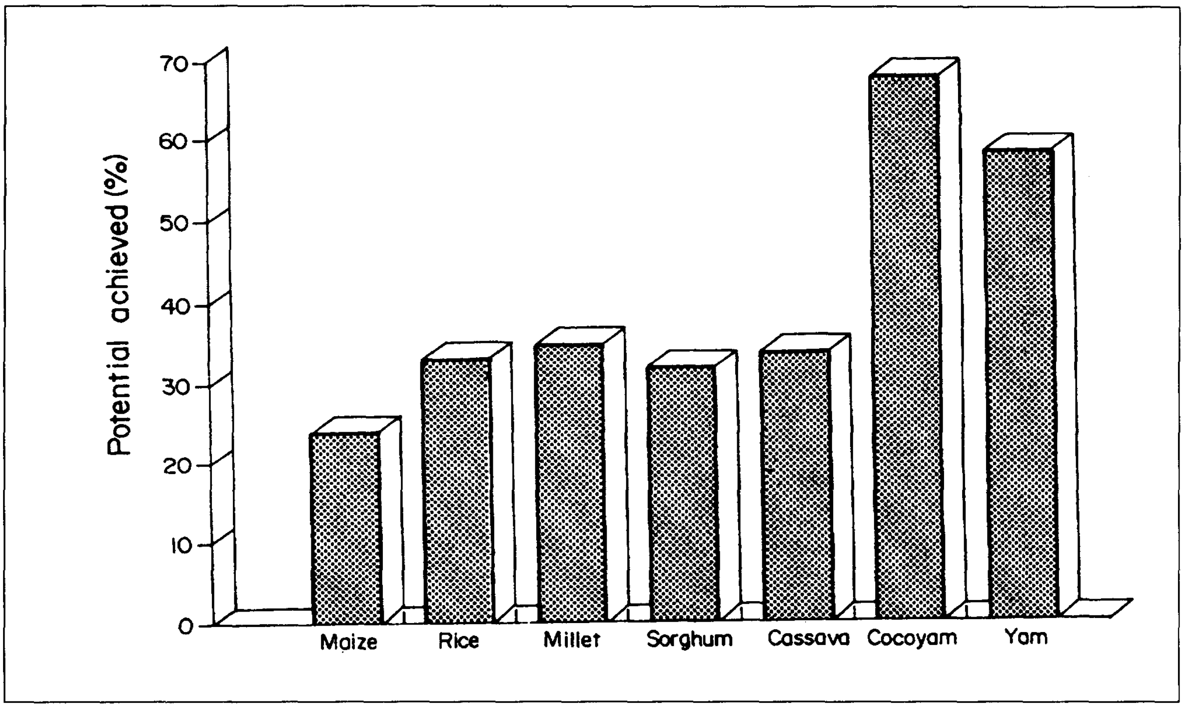

Fig.4.Productivity of staple crops as percentage of potential yields, 1970-1986.

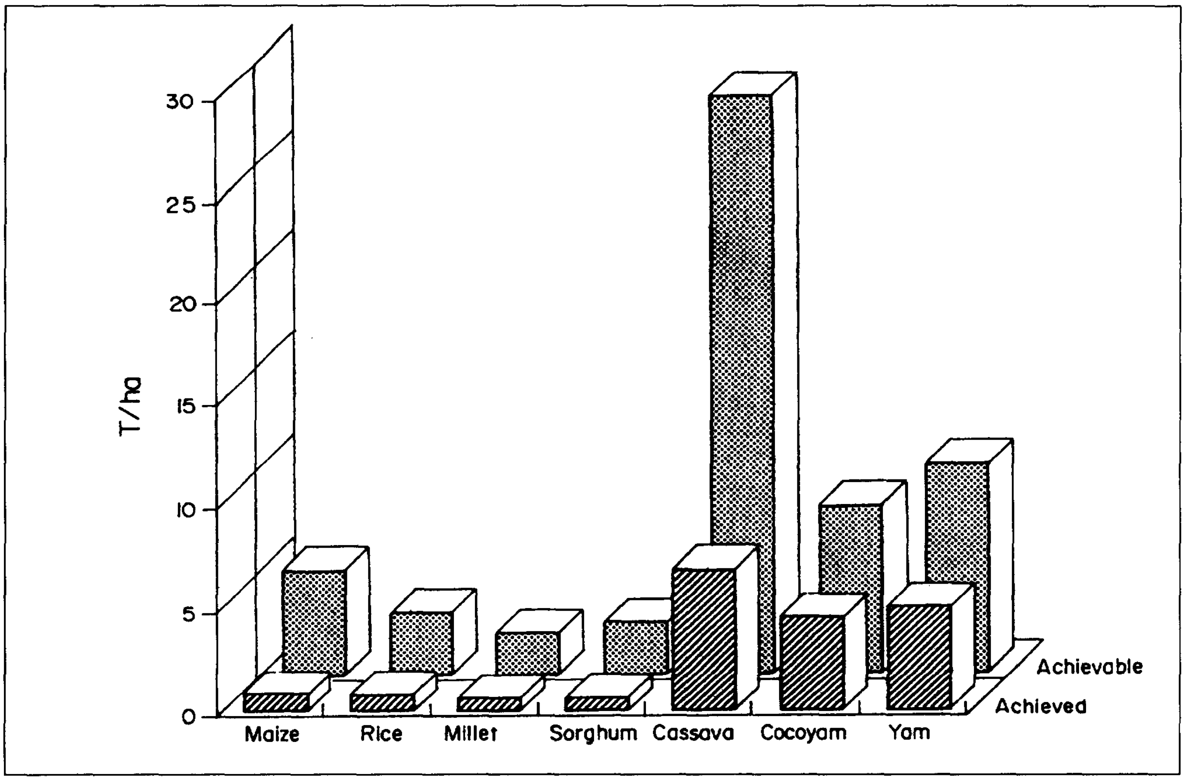

Fig.5.Comparison of present and potential productivity of staple crops, 1970-1986.

sorghum (2%) (ROG, 1987). Slight variations in this general picture occur at the regional level.

Given the scenario of rapid population growth combined with declining soil fertility and environmental degradation outlined above, it is hard to be optimistic of Ghana's future ability of achieving the policy objective of national food security. Increases of both the productivity per unit area cultivated and the area under cultivation would have to be dramatic to realize that policy goal. This is demonstrated by the projections on food demand (Fig. 6).

Holding annual per capita food demand constant, to satisfy demand in the year 2000 the following increases over present production (1987) are required: maize (98%), rice (192%), millet and sorghum (41%), cassava (35%), and yam (173%). The following rates of increase over present (1987) production are required to meet demand in the year 2020 (at the medium and high rates of population increase): maize (206% and 231%), rice (352% and 390%), millet and sorghum (117% and 135%), cassava (109% and 127%), and yam (3575% and 3870%) (Ruddle, 1996).

The Projected Demand for Fish

Various projections have been made of future fish demand in Ghana. Computation here is based on the "herring" (*Sardinella aurita*) catch, the main fish consumed in rural Ghana, and on animal protein supply and demand.

Taking an average normal adult protein requirement of 14.25 $kg.caput^{-1}.y^{-1}$, and projecting it for a 2020 population figure of 28.45 million persons, the annual total animal protein demand of Ghana will be 405,412 t.

On the supply side, fresh "herring" consists of 20.6% protein and smoked "herring" is 66.8% protein (Eyeson and Kankrah, 1975). Further, assuming as at present landings of 300,000 $t.y^{-1}$, of which 225,000 t are smoked and 75,000 t marketed fresh, there is a

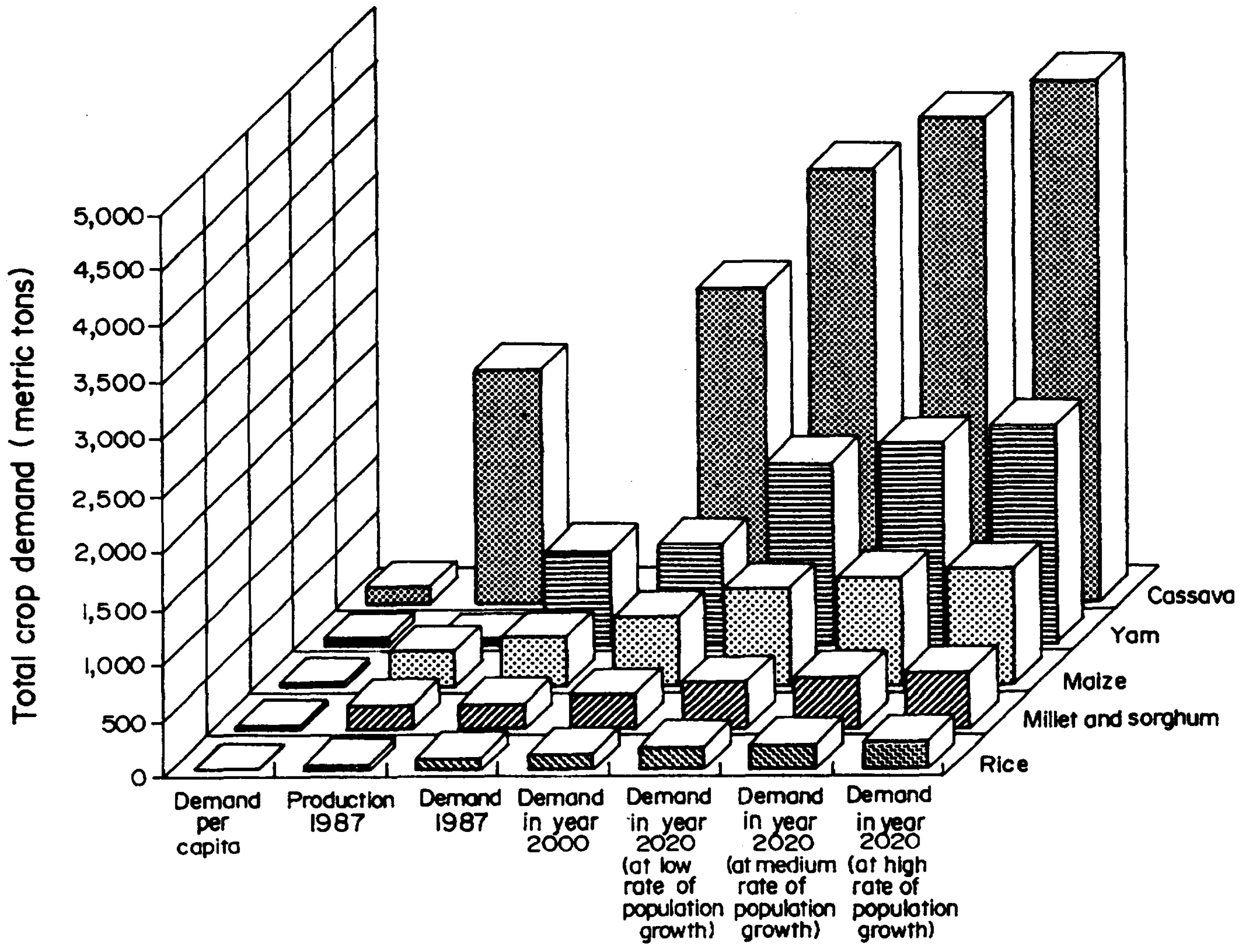

Fig.6.Actual demand per caput and production for 1987 and projected demands for years 2000 and 2020 of cassava, yam, maize, millet and sorghum, and rice.

current production of protein from "herring" of 168,450 $t.y^{-1}$.

Thus to attain the 2020 protein demand, a "herring" landing of 750,000 t would be required. This would require landings to be increased 2.5 times over the present figure. It would translate into a supply of 26.36 $kg\text{-}caput^{-1}.y^{-1}$ (wet wt) of "herring".

However, conventional wisdom, in the absence of reliable stock assessment data, asserts that there is limited potential for further marine fisheries development since stocks are already exploited at a high level (e.g., FAO, 1989b). Nevertheless, the Government of Ghana would like to double fish availability from the current annual average landings of 300,000 t. But this cannot be accomplished from resources available in Ghanaian waters (FAO, 1989b).

Further, as observed above, if present extraction rates continue, Ghana will be without forests by the year 2020. If that is the case, even were 750,000 t of "herring" landed, there would be nothing to smoke them with. Fuelwood would simply either not be available or far to expensive for use in fish smoking. (Unless fuelwood plantation were made, but then these would compete with the by then precious land needed for food production.)

So another economical processing or distribution technology would have to be substituted if "herring" is to remain affordable to poor rural people. But since other forms of processing yield far smaller amounts of protein per fish, the size of the landings would again have to be increased proportionately.

This illustrates vividly, if in a very simplified way, one linkage between environmental degradation (forest destruction), environmental pressures in other ecosystems (the sea) and poverty (need to provide inexpensive fish). The interlocking complexity of this genre of resource-environment-poverty problem facing Ghana is crushing.

Nutritional and Health Situation of Resource-Poor Farm Families

Most rural Ghanaians are hungry for at least part of the year. Prevalent hunger is a serious cause of malnutrition in the country (ROG-UNICEF, 1990). Conditions are worst in the north of the country, where a single annual rainy season permits only one crop cycle a year. Health conditions are worsened because the hungry season and that of highest labor demand coincide. Cultural factors also deprive women of food relative to men. Thus during the food-short season 36% of women are severely underweight, compared with 19% during the rest of the year, whereas the proportions for males are 23% and 3%, respectively (IBRD, 1989).

In general, diets are protein-deficient. Among vulnerable groups this leads to kwashiorkor, which results from a deficiency of protein quantity and quality. A primary caloric deficiency leads to marasmus. Kwashiorkor and marasmus often go together in rural Ghana.

Smoked and fresh marine and freshwater fish is the principal source of animal protein in Ghana. The supply of fish is estimated at 10.4 $g.caput^{-1}.d^{-1}$, compared with 7 from milk and its products (excluding butter), 44 from meat and offal, and 2 from eggs (Sefa-Dedeh, 1981).

Small quantities of fish are generally consumed daily. The main source is marine fish, particularly the seasonally abundant "herring". "Herring" is mainly consumed fresh in the coastal regions, and elsewhere smoked is the preferred form. Consumption is greatest in the coastal and west-central parts of Ghana, at an estimated 10+$g.caput^{-1}.d^{-1}$, compared with 6-9 $g.caput^{-1}.d^{-1}$ in the interior of the southern part of Ghana, 3-5 $g.caput^{-1}.d^{-1}$ in the northern-central area, and less than 3 $g.caput^{-1}.d^{-1}$ in the northern zone (Annegers, 1973) (Fig. 7). (However, these figures should be treated with caution, since they are 20 years old, probably do not include freshwater fish, and almost certainly were not based on comprehensive household surveys.)

Fish is usually consumed together with a dietary staple, usually as an ingredient of a soup or stew (Whitby, 1968; Dede, n.d.). During the peak season fish may be marketed fresh. However, most of the catch is smoked to preserve product quality for long distance transportation to the interior and longterm storage. Sun-dried fish is also powdered and used as a flavoring ingredient in soups and stews, and fermented fish is similarly added as a condiment.

In Ghana it was estimated that 75% of the population regularly consumes, when seasonally available, "bushmeat", the meat of wild animals, principally small mammals, snails, birds, caterpillars, termites, and other insects (Asibey, 1986, cited in Falconer, 1990). But there is no reliable information on household levels and frequency of bushmeat consumption (Falconer, 1990). For Ghana, most estimates derive from the research conducted by Asibey, who estimated that in two districts of southern Ghana bushmeat contributed 44% and 31% of the protein consumed (and fish another 35% and 31%) (Asibey, 1986).

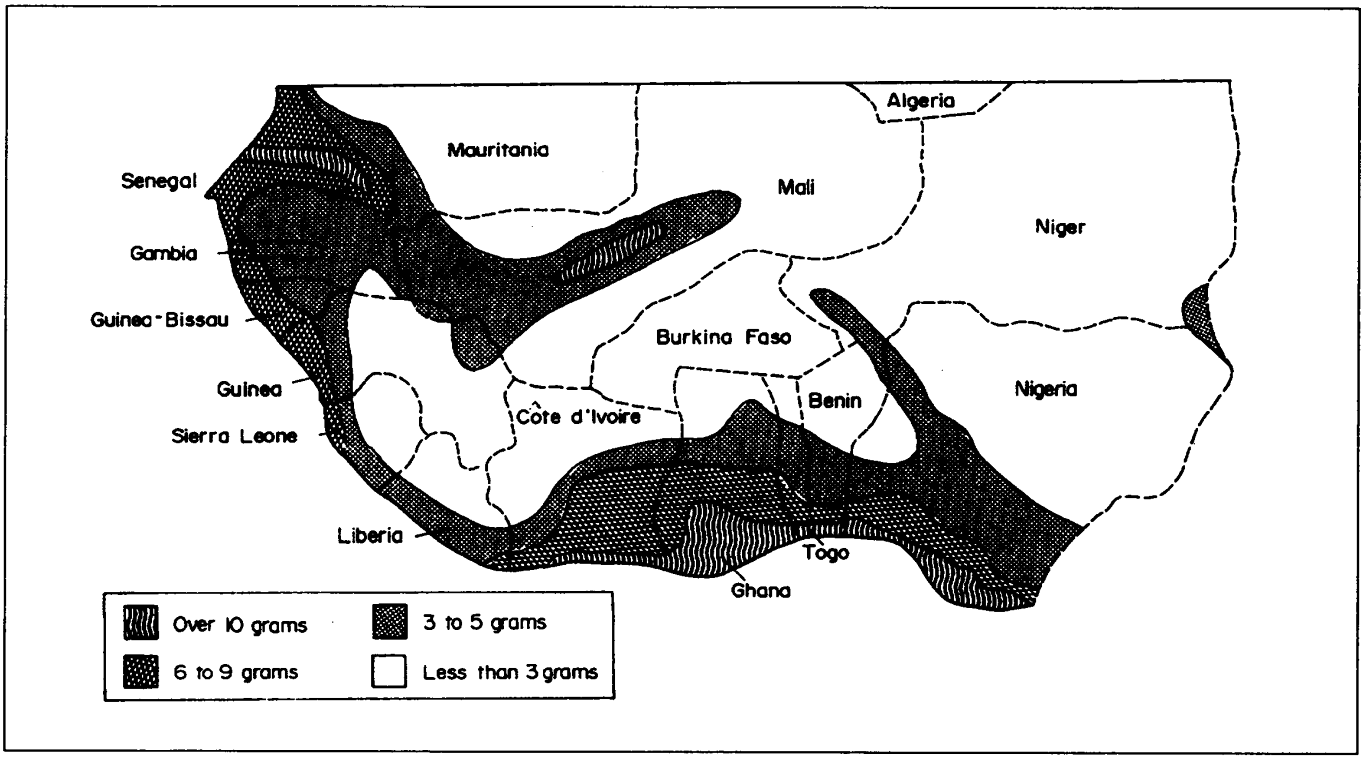

Fig.7.Daily per caput fish protein consumption in West Africa (adapted from Annegers, 1973.)

The national daily per capita consumption of bushmeat has been estimated at 1.8 g (Clottey, 1971) and 1.7 g (compared with 1.6 g from domestic sources) (Asibey, 1974). A 1968 nutrition study estimated that in Ghana 9 $g.caput^{-1}.d^{-1}$ of bushmeat and 1 $g.caput^{-1}.d^{-1}$ of snails were consumed in rural forested areas; compared with 1 $g.caput^{-1}.d^{-1}$ and 9 $g.caput^{-1}.y^{-1}$ respectively in coastal areas (where marine fish is of far greater importance) (Genelly, 1968).

Although many farm households keep smaller domestic animals (chickens, goats and sheep), they are not usually a regular source of animal protein (Asibey, 1974b). Rather they are consumed only at festivals or ceremonies. But mainly they are sold, often as a last resort, to purchase staple foodstuffs or inputs required for cropping, as in the Dagbon area of Northern Ghana (Abu, 1992). The grasscutter (*Thyronomys swinderianus*) has been successfully domesticated and raised experimentally in Ghana. In many parts of Ghana, animal husbandry is precluded by endemic trypanosomiasis.

Principal sources of vegetable protein are the cereals millet (*Pennisetum* sp.), sorghum (*Sorghum* sp.), maize (*Zea mays*), and rice (*Oryza glabberrima*). Cereals are of greater dietary importance in the drier areas of the country, although maize is grown throughout Ghana.

Legumes are also an important source of vegetable protein. Those of principal importance in Ghana are peanut (*Arachis hypogaea*), pigeon pea (*Cajanus cajan*), chickpea (*Cicer arietinum*), lima beans (*Phaseolus lunatus*), kidney bean (*P. vulgaris*), cowpea (*Vigna unguiculata*), and bambara groundnut (*Voandzeia subterranea*). The most widely consumed throughout the country is cowpea (Sefa-Deddeh, 1981).

Wild plants are collected from forest and cropped and fallow fields. They provide *inter alia* leaves, nuts, oils, fruits, roots, and fungi, impart diversity and flavor to basic diets, as well as providing protein, energy, vitamins, and essential minerals. Wild plants are an important reserve resource during food-short seasons, especially prior to the new harvest, when old food stocks have largely been either consumed or sold. Unfortunately, there is little useful data on the frequency and rate of consumption of such products, or of their nutritional value (Falconer, 1990). In one Ashanti Region village 28 plants were commonly gathered and consumed, mostly as snacks or as flavoring agents in sauces and soups (Osei-Owusu, 1981). The oil palm (*Elaeis guineensis*), from secondary growth vegetation, is probably the wild plant most widely exploited throughout West Africa. The fruit and kernel provide edible oil, and the sap is processed into palm wine and alcohol. The palm is estimated to provide 10% of the total energy consumption of regional diets, and is an important source of Vitamin A (Nicol, 1972 cited in Falconer,1990).

Diet composition in resource-poor farm households in Ghana is primarily a function of the staple crops grown on the farm. Thus low protein-calorie ratios of under 10% occur principally in humid areas unsuited to grain cultivation, and where the staples are starchy root crops, particularly cassava and cocoyams. Thus protein energy malnutrition (PEM) is a major problem for resource-poor farm families in the humid regions of Ghana.

Low ratios of 10-11.9% occur in areas where the main crop combination is rice-maize-yams. In contrast, the drier savanna zone, where the principal crops are millet, sorghum and legumes, which are consumed with small quantities of fish, exhibits moderate rates of 12.0 - 13.9% (which are comparable to rates for Europe and North America).

Not all members of resource-poor small farm households have equal access to food produced on-farm. Thus some food deficiencies within the small-farm family arise because access to food, and particularly to proteins, is unequal. Male heads of household, in their supposed role as principal food provider, often have rights to the choicest portion of a meal, especially to the meat (Sefa-Deddeh,1981). Further, depending on ethnic group, protein-rich food may be denied by taboo to children and lactating and pregnant women. In parts of Ghana such persons are denied meat, eggs, milk, fish, snails, and lobsters (Dovlo *et al.*, 1975). Thus those with least access are the two most nutritionally vulnerable groups; children and pregnant and lactating women.

Malnutrition is a serious problem for women and children in rural Ghana (ROG-UNICEF,1990). The problem has several major facets: Protein-energy malnutrition (PEM) together with associated micro-nutrient deficiencies, food shortage (especially in the pre-harvest months), and food consumption.

Protein-Energy Malnutrition (PEM)

A 1986 survey revealed that among pre-school children per capita calorie intake was only 40-70% of requirements (ROG, 1986). The same survey also showed that 58% of children aged 0-5 years were 80% below age-for-weight standards (alarmingly, this was twice the rate recorded in the first such survey, conducted in 1961-62); 40% were 80% below the weight-for-height standard (a measurement of wasting or acute undernourishment); and 8% were suffering from either kwashiorkor or marasmus. The survey showed that 51.5% of children below the age of 5 were below 90% of the standard, and thus were stunted or clinically malnourished, as measured by height-for-age.

Women, particularly those either lactating or pregnant, are badly affected by PEM. A 1987 survey showed that 69% of women tested in antenatal clinics were anaemic (IBRD, 1989). Again, conditions are worst in the north of Ghana, where 65% of pregnant and 45% of non-pregnant women showed symptoms of PEM, compared with 43% and 30% in the south (IBRD,1989). Conditions are much worse in rural than in urban areas, owing to the heavy manual labor performed by women (ROG-UNICEF,1990). Cultural factors add to the problem in those ethnic groups where taboo denies eggs and meat to pregnant women (ROG-UNICEF,1990).

Micro-Nutrient Deficiencies

Malnutrition is accompanied by micro-nutrient deficiencies that result from a lack of vitamins and essential minerals. This lack results from poor diet and the increased intake required to handle the physical stress of infections, injuries and the disproportionate consumption of other nutrients.

(a) Vitamin A Deficiency: This results in night blindness and increased mortality among young children. Although long known to be a public health problem in the north of Ghana, research in the Central Region of southern Ghana revealed that most children under 5 years-of-age were suffered from it (NMIMR,1984). This problem could be overcome were (1) more of the foods rich in vitamin A provided to children, and (2) were more whole small fish, red palm oil, dark-green leafy vegetables, colored vegetables, and fruits available to households.

(b) Iodine Deficiency Disorder (especially goitre): Goitre is a particular problem in the Upper regions, where 10.7% of the surveyed population is afflicted (ROG, 1986). The deficiency is attributable to both natural and human factors. Among the latter is that iodine-rich vegetables are hardly consumed and that when they are eaten, the nutrients are washed and boiled out. Another likely cause is that soil erosion in the arid areas has stripped away the iodine content in soils, such that it cannot be absorbed by crops (ROG-UNICEF, 1990).

(c) Iron Deficiency Anaemia: This condition is common throughout the country, and affects most pregnant women. The main cause is thought to be poor absorption from cereal-based diets (ROG-UNICEF, 1990). But Watson (1971) commented that in the north of Ghana, iron levels in cereals were higher than expected. This is exacerbated by blood loss owing to malaria, bilharzia and hookworm (ROG-UNICEF, 1990).

Thus malnutrition among resource-poor farmers in Ghana results basically from an insufficient staple and complementary crop production, implying that the intake of either farm-produced or purchased nutrients is inadequate This is exacerbated by labor demands, general ill-health, and cultural factors governing intra-family food consumption. Food production both at the national level as well as on the majority of small farms does not meet demand.

Hypothetical Nutritional Status

The principal farming systems in the three main agricultural ecological zones of Ghana were modelled with simple bioeconomic spreadsheets based on existing and actually measured information. The graphs that follow are intended to demonstrate the relative roles of the various crops cultivated in satisfying the nutritional demand of a farm family. The scales of the "y-axes" have been varied for visual clarity and to accommodate the very large relative productivity of crops for some nutritional elements.

(1) Deciduous Forest and Rainforest Zones

(A) Maize-Cassava Cultivation (Fig. 8)

In this case the household demand for protein, iron, vitamin A, and thiamine is more than satisfied by farm yields. But calorie, calcium, riboflavin, and niacin yields are low and mostly below 50% of demand. The important role of vegetable cultivation is immediately obvious in increasing Vitamin A yields from just 50% of demand to more than satisfying the demand. Similarly, "herring" consumption plays a vital role in iron fulfilling demand. Without "herring" the inadequate provision of calcium and niacin would be even worse. In this case farmed fish mostly adds to animal protein intake, and further increases the already satisfied protein demand. It also increases calorie and calcium availability minimally, but not enough to satisfy demand totally.

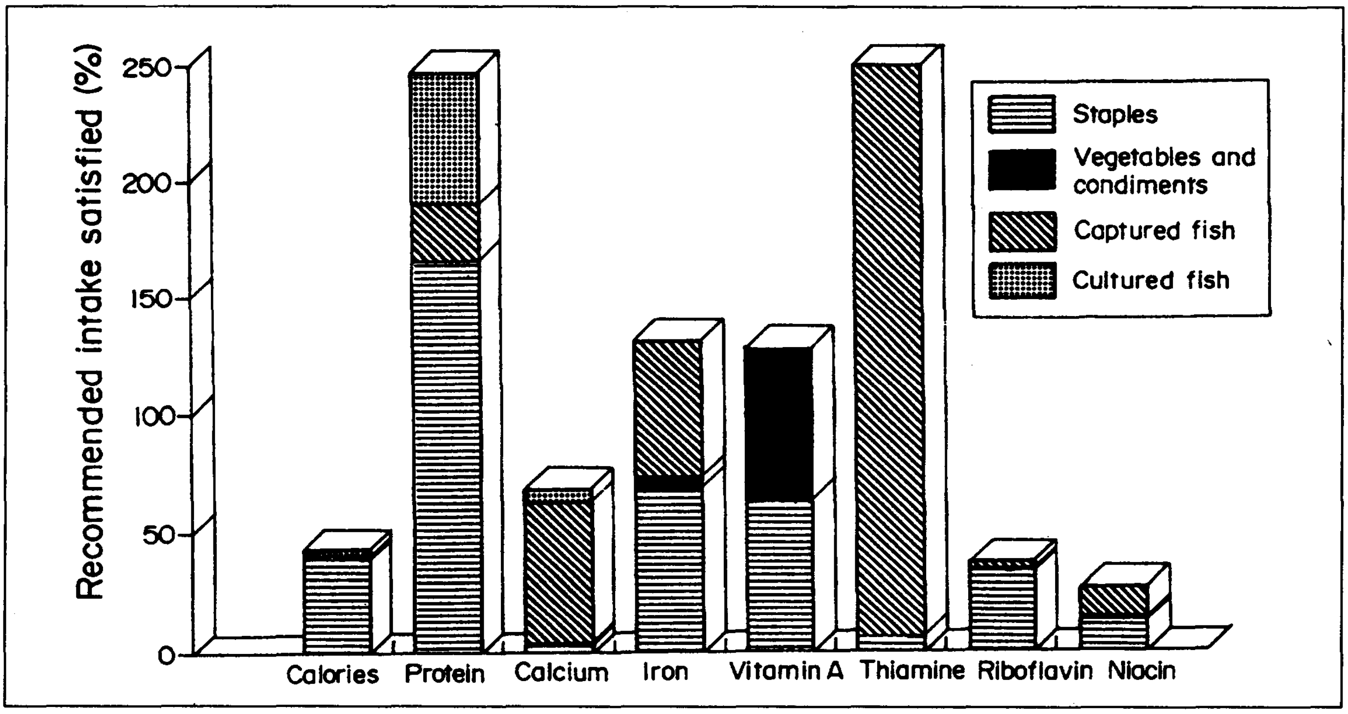

Fig.8.Hypothetical nutritional status: Deciduous Forest and Rainforest zones (first and second year, maize and cassava; third, cassava).

(B) Maize Cultivation (Fig. 9):

Here the nutritional role of vegetable and farmed fish would be very important. The fish would double protein supply such that it would just meet demand. It would also add a little to the low level of calcium supply. Vegetable production would boost an already high output of Vitamin A and would raise a critically low production of Vitamin C to nearer satisfaction of demand. But the overall situation would remain poor with respect to intake of vitamins, calcium and calories. A much wider diversification of the staple crop assemblage is essential.

(C) Maize-Plantain-Cassava Cultivation (Fig. 10):

Calories, calcium, riboflavin, and niacin are again poorly supplied. (Note that the very large Vitamin C supply, which is 10 times greater than demand, has been deleted from Fig. 13.) Farmed fish would add quality to the protein supply, as well as contributing marginally to improving a poor calorie and calcium supply. Vegetable production would add mainly to the already more than adequate supply of vitamin A.

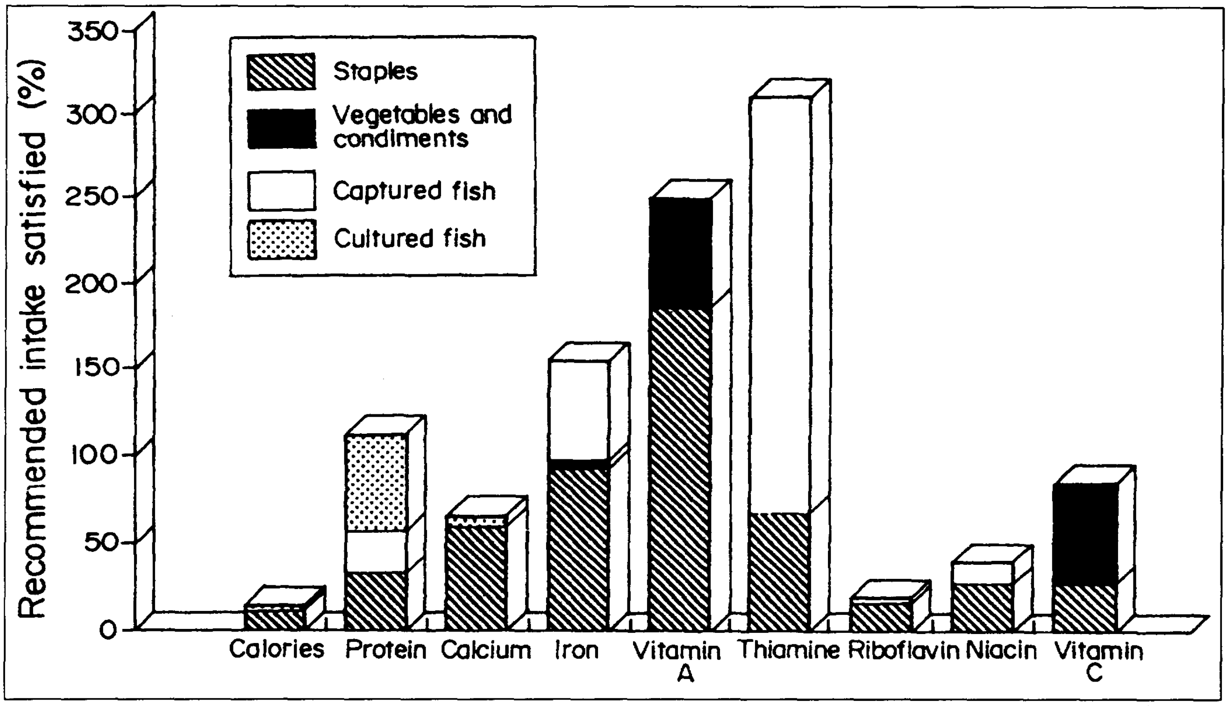

Fig.9. Hypothetical nutritional status: Deciduous Forest and Rainforest zones (first, second and third year, maize).

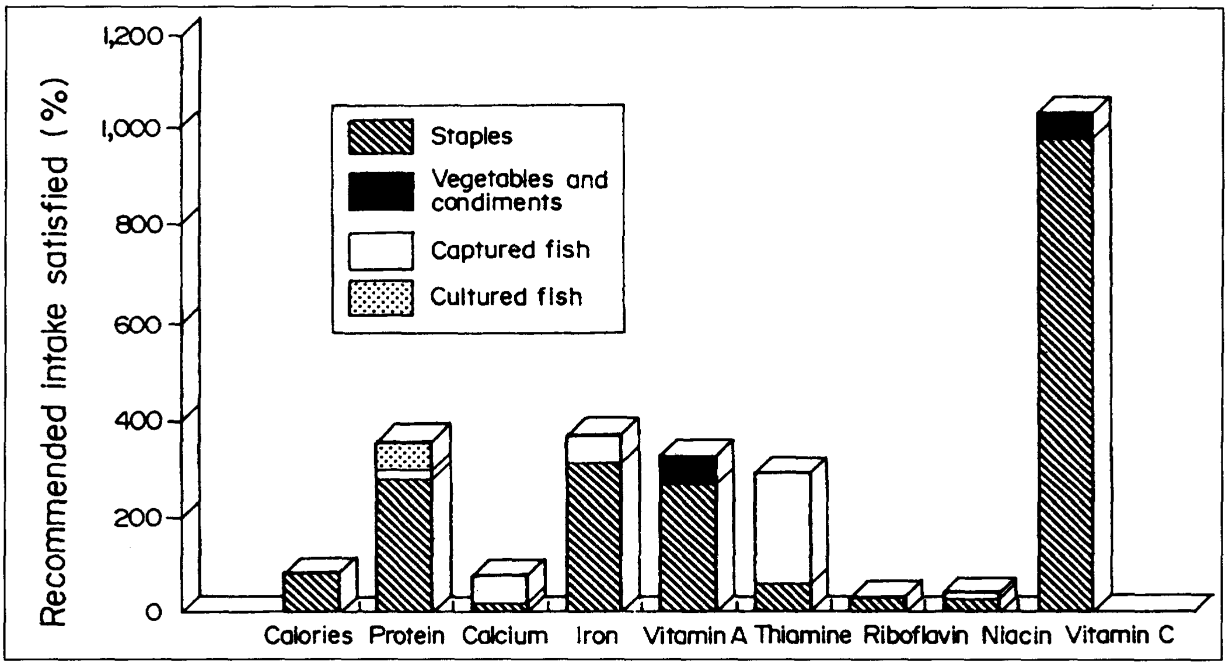

Fig.10. Hypothetical nutritional status: Deciduous Forest and Rainforest zones (first and second year, maize and plantain; third, cassava).

(2) Transition Zone

(A) Maize-Cassava Cultivation (Fig. 11):

In this case farmed fish would play a very important role in doubling the supply of protein, such that the total demand would then be satisfied. It would also add marginally to a still deficient calorie and calcium supply. The main nutritional contribution of vegetable production would be to turn a seriously deficient supply of Vitamin A into one where demand is met.

(B) Yam-Peanut Cultivation (Fig. 12):

In terms of farmed fish, the situation is essentially a repeat of the previous model. The role of vegetables in supplying vitamins A and C is also noteworthy.

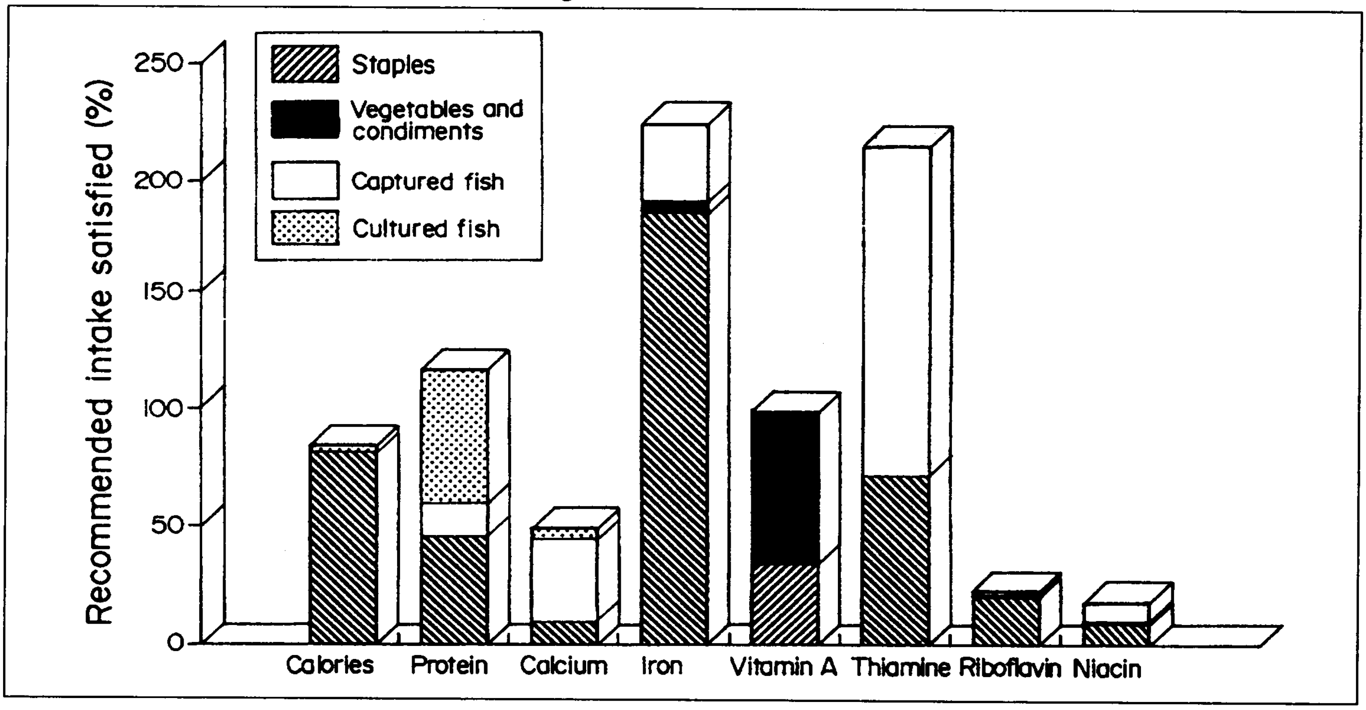

Fig.11.Hypothetical nutritional status: Transition zone (first year, maize and cassava; second, cassava; third, no crop).

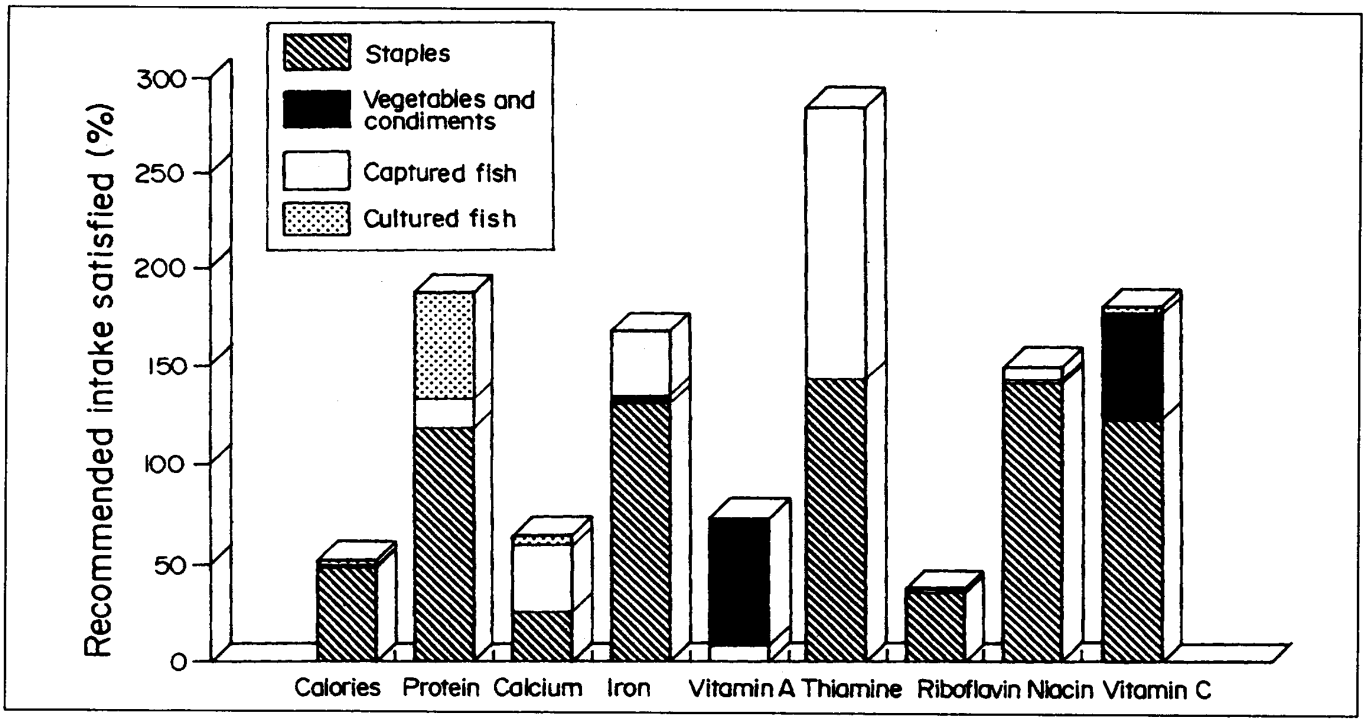

Fig.12.Hypothetical nutritional status: Transition zone (first year, yam; second, peanut; third, no crop).

(C) Yam-Cassava Cultivation (Fig. 13):

The situation is again similar to the preceding model. Farmed fish would ensure increased supplies of protein - both quantitatively and qualitatively - such that demand becomes satisfied. It would increase marginally the calories and calcium supplied, but both would remain deficient. Vegetables would have a vital role in supplying vitamin A.

(3) Guinea Savanna Zone

Despite variations in detail, the nutritional situation is very similar for all the crop combinations modelled in the Guinea Savanna Zone. That being the case, only two examples of the models are given here.

(A) Sorghum-Millet-Maize-Cassava (Fig. 14):

Farmed fish would add quantity and quality to the protein supply, such that it would become satisfied. And it would add marginally to calorie, calcium and vitamin C supply, all of which, however, would remain below demand. Vegetables would be critically important. They would double Vitamin A supply so that it would then exceed demand, and they would become the main supplier of Vitamin C, although only about 75% of the demand would be satisfied.

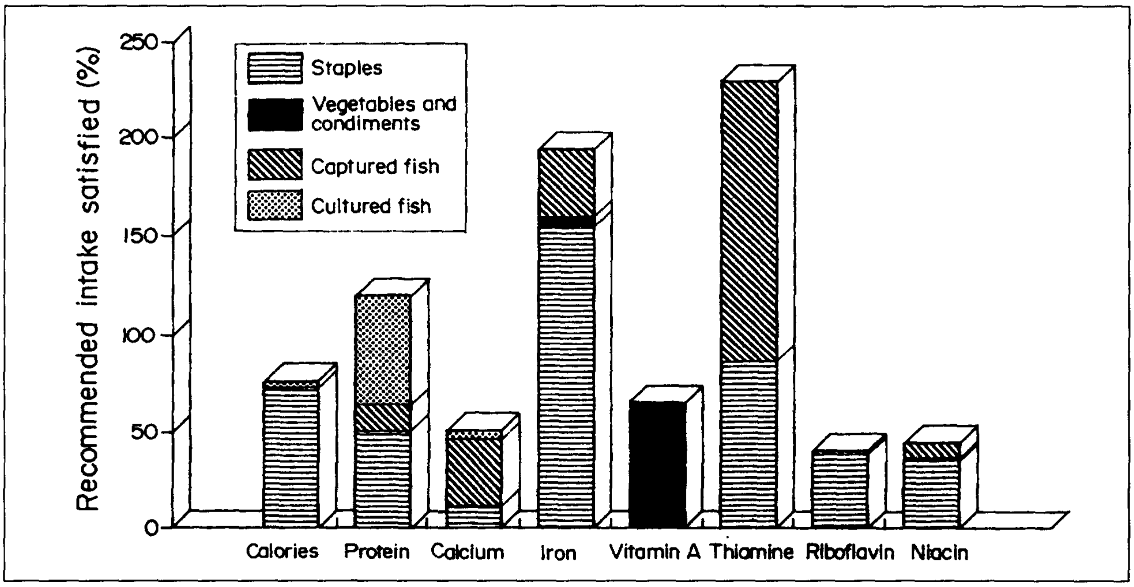

Fig.13.Hypothetical nutritional status: Transition zone (first year, yam; second, cassava; third, no crop).

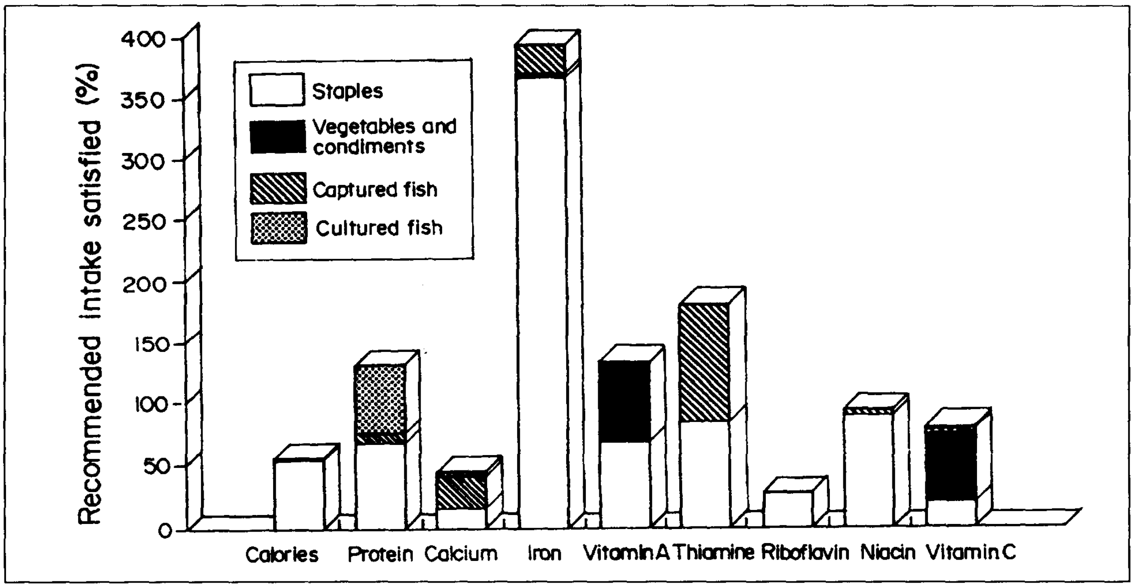

Fig.14.Hypothetical nutritional status: Guinea Savanna zone (first and second year, sorghum, millet and maize; third, sorghum, millet, maize and cassava).

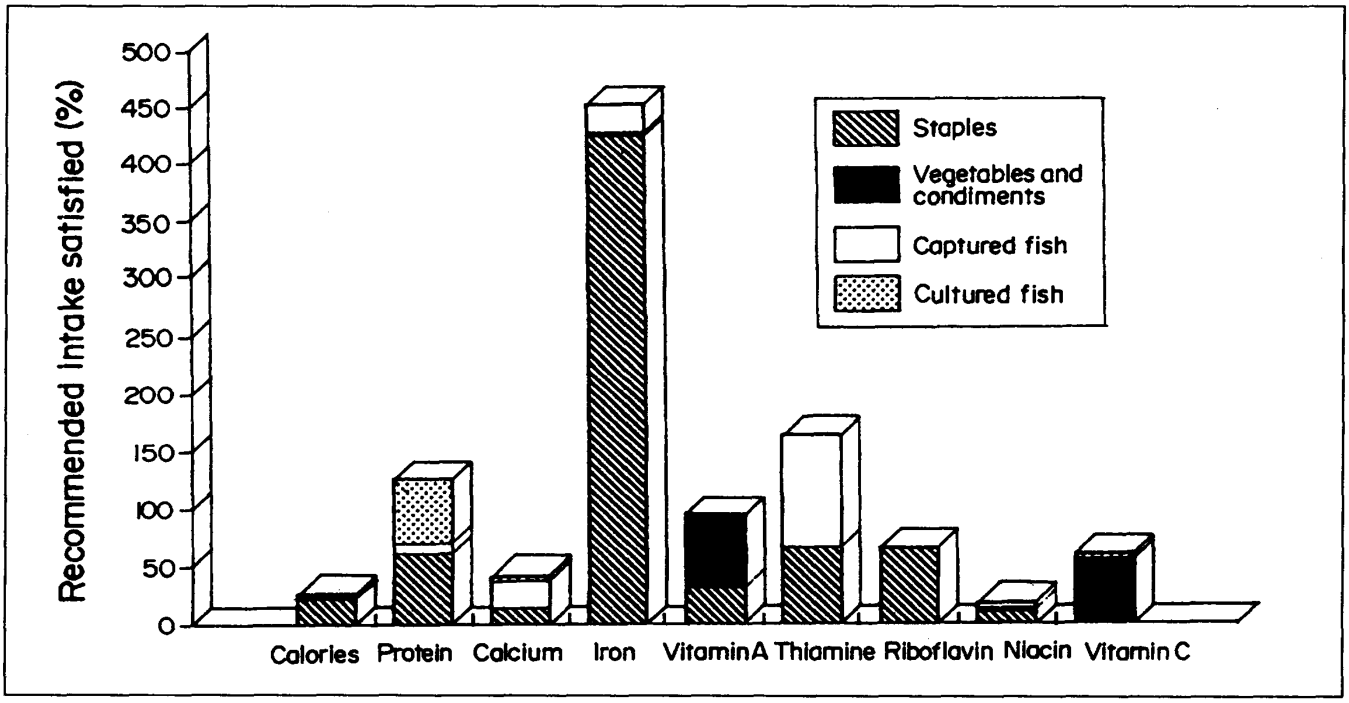

Fig.15.Hypothetical nutritional status: Guinea Savanna zone (first, second and third year, sorghum, millet and cowpea).

(B) Sorghum-Millet-Cowpea Cultivation (Fig. 15):

The nutritional situation is basically poor. Farmed fish would increase the protein supply above demand. It would also add marginally to calorie, calcium and vitamin C supply, all of which, however, would remain below demand. Vegetable production would again be important, although still insufficient, in increasing the supply of vitamins A and C.

Pond and Vegetables and Improved Household Incomes

In all farm types modelled, the addition of pond and vegetable components would lead to a dramatic increase in household net incomes. Such an improvement would range from a "low" of 229% to a high of 697%. This, of course, reflects the net value of the original crop assemblage, since the "low" of 229% occurs in the model where the crop-based cash income is highest at USD 1138.ha^{-1} and the "high" of 697% occurs on a farm with a crop-based income of USD 245.ha^{-1} (Fig. 16).

Whereas total economic improvement from the addition of a vegetable-crop component is excellent, it is important to analyze the relative role in this of the vegetables and the fish (Fig. 17). In none of the 13 models does the value from fish production based on a pond size of 0.01 ha (100 m^2) exceed 2% of the total production of the farm unit. In only 4 models did fish production yield as much as 2% of the income. Most (11 models) demonstrate that only 1% of the total on-farm income would be derived from fish.

Even were the size of the pond component expanded to 0.06 ha, fish production would contribute no more than 4% of total on-farm income; the bulk of the extra income generated would come from the production of vegetables. Further, in all models the value of vegetable production would far exceed that of the staple crops: vegetables contributing from 55-84% of the value of total farm economic output, compared with staples that would contribute 14-43% (Table 1).

	0.04 ha plot			
Crop	Yield (t)	Value (USD)	Yield (t)	Value (USD)
Okra	0.18	37.44	4.5	936
Tomato	0.71	48.00	17.77	1,200
Onion	0.024	16.00	0.60	400
Eggplant	1.008	30.72	25.20	768
Pepper	0.104	48.00	2.60	1,200
Cabbage	1.070	1,280.00	26.67	32,000
Total	-	1460.16	-	36,504
	0.06 ha pond			
Fish	0.26	164.7	4.40	2745.30

Table 1: Projected yields of vegetables and fish on vegetable plots of 0.04 ha and 1.0 ha and in ponds of 0.06 ha and 1.0 ha

The Potential Role of IAA in Fulfilling Policy Goals

The following extrapolation is based on a 5% adoption rate among the 2.3 million national population of small-scale farmers. This 5% rate, which is conservative, is based on a site and water supply feasibility reconnaissance survey of the Mampong Valley, Akuapem, combined with an informal farmer attitudinal survey regarding adoption of aquaculture.

Extrapolation is also based on a vegetable field of 0.04 ha and a pond size of 0.01 ha. The vegetable plot size is double that at Mampong (Ofori *et al.*, 1996). Although a 100 m^2 pond is extremely small, and its contribution to farm cash incomes minimal, its demonstrated nutritional importance is considerable. For comparison projections have also been made based on a 0.06 ha pond, and a 1.0 ha pond. The rates assumed are based on those being achieved now at Mampong, and extrapolated.

If these figures are multiplied by 5% of the 2.3

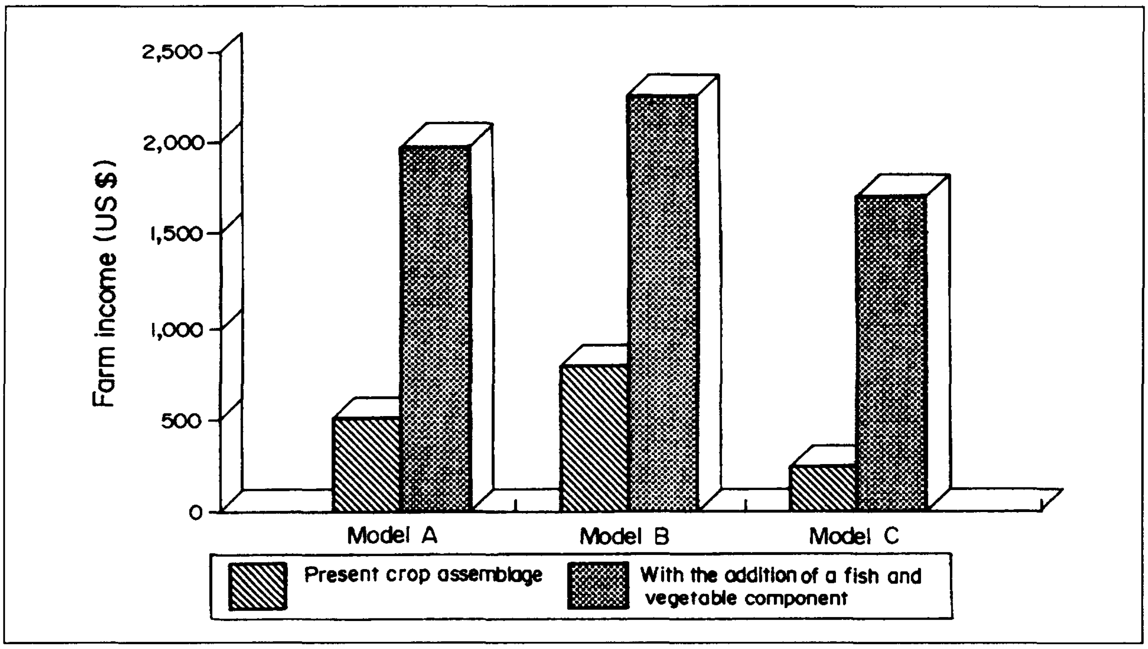

Fig.16.Change in net farm income with the adoption of an IAA system: examples from the Transition Forest zone.

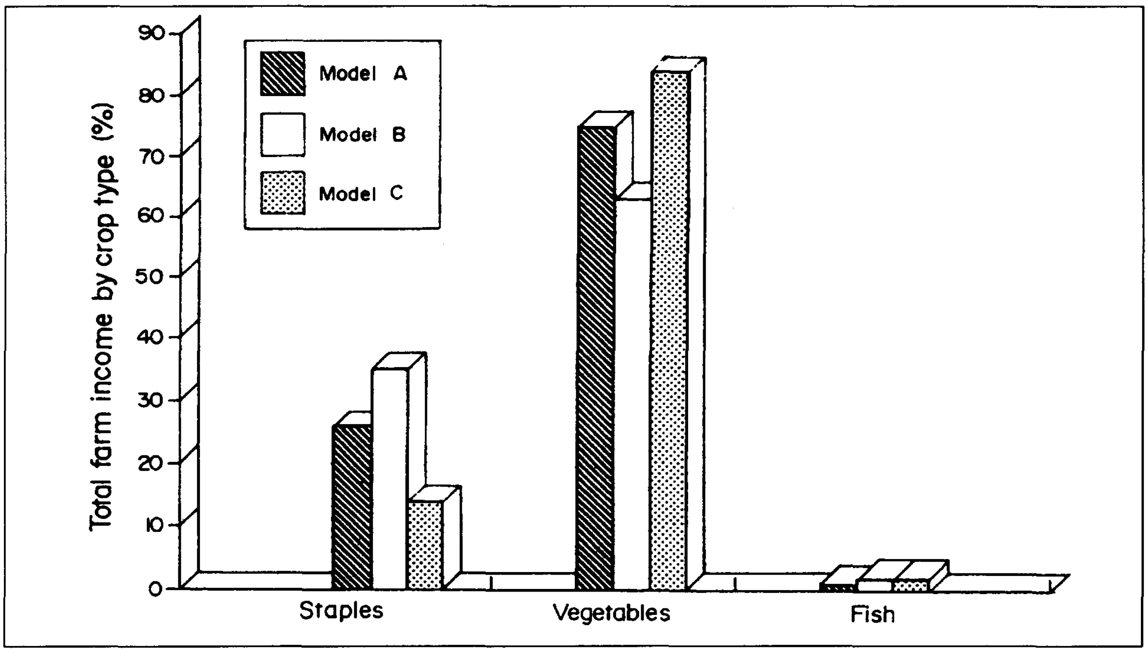

Fig.17.Economic impact of pond-vegetable component: examples from the Transition Forest zone.

million small-scale farmers in Ghana, there would be a total of 115,000 adopters of vegetable cultivation and fish farming. The projected national levels of production would be as shown in Table 2.

Table 2: Vegetable and farmed fish production projections for 0.04 ha and 1.00 ha of vegetables and 0.01 ha and 0.06 ha of pond (yields in t)

	0.04 ha plot	1.00 ha plot
Okra	20,700	517,000
Tomato	81,650	2,043,550
Onion	2,760	69,000
Eggplant	115,920	2,898,000
Peppers	11,960	299,000
Cabbage	123,050	3,067,050
	0.01 ha pond	0.06 ha pond
Fish	5,060	29,900

Projected Protein Demand in 2020 and the Capacity of Farmed Fish to Fulfil it

A projected 405, 412 $t.yr^{-1}$ of animal protein will be the demand of the population of Ghana in the year 2020. Holding fish landings constant, this will result in a deficit of 236,962 $t.yr^{-1}$.

Since sun-dried tilapia contains 71.9% protein (compared with 67.5% for smoked tilapia, and the fuelwood crisis could preclude that), it would require 305,680 t of tilapia to meet this demand. This demand could be met using ponds of different sizes. But each pond size has different implications at the national level:

- If the current average pond size of 0.01 ha (100 m^2) was adopted nationwide, to produce 305,680 t of tilapia would require 6.9 million ponds. This implies 6.9 million adopters, or roughly three times the present number of small-scale farmers. It would require - at 30 farmers per extension agent - 230,000 extension agents. Clearly, this is not an option.

- A national total production of 305,680 t tilapia could also be achieved using 1,157,883 ponds of 0.06 ha. This would require the efforts of about 1.2 million adopters, or about 50% of the existing number of small-scale farmers. Again, this is not a viable option.

- However, when ponds or a set of ponds, of 0.24 ha are used, the total number required nationwide becomes 289,470. This would represent a 12.5% adoption rate among the existing population of small-scale farmers.

The last option is worthy of serious consideration. Obvious implications are the need for a reliable water supply. That will mean tying into community projects to reafforest denuded watersheds to ensure that formerly perennial springs become so again. This would have the additional merit of decreasing the rate of soil erosion, of providing locally accessible fuelwood, and, depending on species, materials for direct human consumption or other uses, like fodder, fish feed or manures.

Extension demand would not be exorbitant. It would require some 9,600 extension personnel (at 30 farmers per extensionist). This could be achieved in a variety of ways; using NGOs for example, training local master farmers, or using the "farmer-teaches-farmer" approach, as in the Ghana Rural Reconstruction Project.

Labor demands would not be unrealistic. Based on a labor demand of 14 days to construct a 0.01 ha (100m^2) pond at Mampong, a 0.24 ha pond would require an input of 336 mandays. This would cost USD 250 at the current official minimum wage of USD $0.75.d^{-1}$, and USD 1003 at the rate of USD $3.2.d^{-1}$ plus lunch, currently demanded by agricultural laborers.

But the main point is that the year 2020 population will not be reached for another 27 years, and there is ample time for farmers to progressively expand their pond area as their income increases (particularly from the associated vegetable field).

Capital can be raised in a variety of ways. The obvious way is from the production of the vegetable field. Other obvious sources would be the "fish mammies" (such entrepreneurial women have offered to purchase the entire output of Mampong ponds) and other rural entrepreneurs.

Conclusion: the Role of Integrated Systems

Whereas most small-scale aquaculture in Africa is of the extensive type, efforts should be made to promote its transformation to semi-intensive systems, and all projects to introduce aquaculture should promote semi-intensive systems from the outset. Given the general inability of small-scale farmers in Africa to purchase pond inputs to sustain even low level semi-intensive systems, all such efforts must focus on the promotion of integrated systems of agriculture-aquaculture, *i.e.*, the integration of an aquaculture component with existing components of farms, principally crop cultivation, via the flow of energy and materials. In this way inputs derived from those components "drive" the pond, some of the outputs of which, in turn, enhance the performance of agriculture. This integration should be based as much as possible on the utilization of materials produced on farm, supplemented by those obtained from open access or common property resource areas.

Most ecologically sound traditional agricultural systems developed in the humid tropics have been based on a multi-species focus, and so mimic the surrounding (or formerly surrounding) biological environment into which they were projected. The majority of such systems are the various types of shifting cultivation, and among the most complex of purely agricultural variants of such mimetic systems are house garden-plantations. In wetland environments, and better exemplified by those in Asia than by African wetlands, more sophisticated and more highly mimetic of the natural system are integrated ricefield fisheries and the complex, and less commonplace, integrated aquaculture-agricultural farming systems.

The principal ecological attributes of such integrated mimetic systems may be hypothesized as (Ruddle, 1994):-

- a polycultural mimicry of a natural state, with a variety of intercropped species represented by a small number of individuals, thereby replicating tropical habitats in terms of a biological diversity index;
- the maintenance of the natural ecological system into which the agroecosystem is projected, thereby retaining systemic congruity between the cultural system and the ecological system;
- the maintenance of the gross pattern of the natural community while changing selected items of its content;
- the re-cycling and minimizing of losses of energy and materials via the utilization of wastes and products of decay as raw materials;
- natural decay and re-cycling of energy and materials in natural systems is accelerated by human activities, and both largely occur in the biotic community;
- the structural congruence of the multi-layered natural system and the cultural system allows fuller exploitation of trophic levels and heightened environmental protection;
- the multi-layered structure reduces the requirement for energy subsidies and labor inputs; and
- integration permits a fuller utilization of heat, light, moisture and nutrients by species with different habits and nutritional requirements than is possible in unintegrated systems.

The fundamental concept underlying any integrated farming system is that many outputs (sometimes called "wastes" or "by-products") of sub-systems become basic inputs for other sub-systems, rather than just additive components of the overall farm economy. A synergyism is thereby created such that the total productivity of the system exceeds the sum of the individual sub-systems. This results in higher yields for all commodities produced and a wider range of products than could otherwise be obtained per unit area. In addition to producing subsistence and commercial commodities, among other benefits the farm family is assured a regular and balanced diet and a high degree of self-reliance in a range of foodstuffs and raw materials, and thus risks inherent in more specialized farming are spread (Edwards *et al.*, 1988). Under such systems the economic results from any one component are not viewed as important; instead, maximizing the returns from the whole is the objective (Ruddle and Zhong, 1988).

Another fundamental advantage of integrated systems of aquaculture-agriculture, for example, is that pond fertilizers, fish feeds and crop fertilizers are produced locally, within the system, and at either a low monetary cost or at only an opportunity cost (Ruddle and Zhong, 1988), whereas in the absence of integration they would have to be imported from outside the system, usually at considerable expense in terms of capital, time and labor. In semi-intensive fish farming or example, under systems not integrated with either crop production or animal husbandry, supplementary feed usually accounts for some 50% of the total farm operating budget (Schroeder, 1980), and pond fertilizers and other inputs for the field crops comprise a large item of the budget of a non-integrated farm. Hence, in integrated systems in China, for example, profits from the fish component alone are increased by as much as 30-40% (FAO, 1979). Moreover, the uncertainties of supply commonly associated with the use of commercially produced compounded feeds and inorganic fertilizers in developing countries are almost eliminated.

As noted above, a principal physical constraint on aquaculture development in Africa, as well as a prime cause of low labor productivity and high risk in small-scale agriculture, is the pronounced seasonality and unreliability of rainfall. Thus, except where perennial groundwater sources and springs occur, aquaculture must rely on only seasonally available surface water, the volume of which is subject to large intra-and inter-annual variation. As a consequence, particularly in the African context, the control of water must comprise a fundamental element in the design of aquaculture systems. For the small-scale systems addressed here that implies informal irrigation systems, that are locally controlled and managed by communities of small-scale farmers (Woodhouse, 1989)[2].

Aquaculture can play a vital role in informal irrigation, since fishponds can also serve as mini reservoirs, or water collection points, where water is aggregated for fish culture, crop irrigation and livestock watering. An additional function of the pond, particularly in semi-intensive and intensive systems, is as a sump, where nutrient-rich sediments gradually accumulate. This pond mud is dug-out periodically, and supplied to the surrounding crop areas as a substitute, supplement or complement for other fertilizers or mulches. Farm ponds are, then, multi-functional devices that perform several important roles in well-integrated systems of agriculture-aquaculture beyond merely providing a location and medium for fish culture. Not the least important of these is as a focal point in small-scale, localized, informal irrigation systems.

It is important to reiterate the multiple roles of the pond, as well as the symbiotic relationship between pond and vegetable field. The two main symbiotic pathways between vegetable field and pond are (1) as mentioned above, the nutrient-rich pond mud and water delivered to the field; and (2) the use of vegetable waste, such as outer cabbage leaves, as fish food. This multiple role would have the likely effect of gradually raising general farm productivity, although this remains to be demonstrated empirically. Farm ponds are much more than mere "fish ponds", although policymakers tend to see them simply as such. The term "fish pond" is both misleading and limiting, because farm ponds play a variety of roles simultaneously:

- they are the "container" in which fish can be raised;
- when they gradually become sealed against seepage, they are a small reservoir for irrigating high-value field crops (especially vegetables) during the dry season. This role is enhanced if the pond is manured and the fish properly fed such that the pond water becomes nutrient-rich;
- if the pond is manured and the fish fed, the pond is a source of fertilizer for crops from the organically-enriched pond mud that is periodically removed from the pond bottom and spread over the vegetable field;
- as a sediment-trap to catch friable soils eroded from up-stream during the wet season; and
- if well-constructed, as a "buffer" to reduce wet season rainfall run-off and reduce the likelihood of flooding in lowlands and valley bottoms.

References

Abu, K. (1992) Target group survey: Dagbon area in northern Ghana. GGAEP, Tamale.

Addae-Mensah, J. (1979) Socio-economic structure of economic activity in Ghana. Thesis for Diploma in Population Studies, University of Ghana, Legon.

Annegers, J.F. (1973) The protein-calorie ratio of West African diets and their relationship to protein-calorie malnutrition. Ecology of Food and Nutrition 2, 225.

Anon. (1991) Environment and Development in Ghana: Ghana national report. Paper prepared for the U.N. Conference on Environment and Development. Accra, National UNCED Committee.

Asibey, E.O.A. (1974a) Wildlife as a source of protein in Africa south of the Sahara. Biological Conservation 6(1):32-39.

Asibey, E.O.A.(1974b) Some ecological and economic aspects of Grasscutter, *Thyronomys swinderianus* (Temminck) (Mammalia, Rodenta, *Hystricomorpha*) in Ghana. Ph.D. diss., University of Aberdeen, Aberdeen.

Asibey, E.O.A. (1977) Expected effects of land-use patterns on future supplies of bushmeat in Africa south of the Sahara. Environmental Conservation 4(1):43-49.

Asibey, E.O.A. (1980) Traditional hunting in West Africa with special reference to Ghana. In: Nchunga, M.L. (ed.) Wildlife management and utilization,163-180.

Asibey, E.O.A. (1986) Wildlife and food security. Forestry Department, FAO, Rome.

Clottey, J.A. (1971) Wildlife as a source of protein in Ghana. Food and Nutrition in Africa 9:7-11.

Coche. A. (1983) Aquaculture development. CIFA/83/5. FAO, Rome.

Convery, F. and K.A. Tutu (1990) Evaluating the cost of environmental degradation in Ghana. Environmental Protection Council, Accra.

Dede, A. (n.d.) Ghanaian favourite dishes. Anowuo Educational Publications, Accra.

Dovlo, F.E., C.E. Williams, and L.Zoaka (1975) Cowpeas: Home preparation and use in West Africa. IDRC-055e, IDRC, Ottawa.

Edwards, P., R.S.V.Pullin and J.A.Gartner.(1988) Research and education for the development of integrated crop-livestock-fish farming systems in the tropics. ICLARM Studies and Reviews 16. ICLARM, Manila.

Ewusi, K., S.Y. Atsu and L.O. Gyekye (1983) Land utilization and labour productivity in agriculture in Ghana. Technical Publication 46, Institute of Statistical, Social and Economic Research, University of Ghana, Legon.

Eyeson, K.K. and E.K. Ankrah (1975) Composition of foods commonly used in Ghana. Food Research Institute, Accra.

F.A.O.(1975) Aquaculture Planning in Africa. FAO, Rome.

F.A.O.(1979) Aquaculture Development in China. FAO, Rome.

F.A.O. (1989a) Ghana: land resource management study identification mission, vol. 1. Report 103/91 CP-GHA 28. FAO-World Bank Cooperative Programme. FAO, Rome.

F.A.O.(1989b) Sector study: Ghana fisheries sector review. 10/89 CP-GHA 22SR. Report of the FAO/World Bank Cooperative Programme Investment Centre. FAO, Rome.

Falconer, J. (1990) The major significance of 'minor' forest products: The local use and value of forests in the West African humid forest zone. Community Forestry Note 6. FAO, Rome.

Friar, F.A. (1987) The state of forest resources in Ghana. In: The state of natural resources. Environmental Protection Council, Accra.

Genelly, R. (1968) Interim report to the Government of Ghana on wildlife conditions. FO: TA/GHA Forestry Department, FAO, Rome.

IBRD (International Bank for Reconstruction and Development). (1989) Ghana: Population health and nutrition sector review. IBRD, Washington D.C.

Laan, van der E.(1984) Factors contributing to the rapid development of small-scale irrigation schemes along the Senegal River, Agricultural Administration 17: 203-213.

Leung, W-T.W., F. Busson and C. Jardin (1968) Food composition table for use in Africa. F.A.O. and U.S. Department of Health, Education and Welfare, Public Health Service, Rome and Washington D.C.

Mensah, P. (1987) FAO/UNDP GHA/85/011 pilot project for promotion of integrated agricultural development in Sekyere District, Ashanti Region, Ghana. Farm and Household Survey, Final Report: Analysis Vol. 2. Ministry of Agriculture, Accra.

MOA (Ministry of Agriculture).(1988) Agricultural land use of Ghana. Ministry of Agriculture, Accra.

Nichol, B.M. (1972) Food from forests. Report on an FAO conference on the establishment of cooperative agricultural research project between countries with similar ecological conditions in Africa. Document 16, FAO, Rome.

NMIMR (Noguchi Memorial Institute of Medical Research).(1984) Growth and diarrhoeal disease surveillance in a rural Ghanaian preschool child population at Fetteh, Central Region. Accra, NMIMR.

Ntiamoa-Baidu, Y. (1987) West African wildlife: a resource in jeopardy. Unasylva 156(39):27-35.

Ofori, J.K., A. Asamoah and M. Prein (1996) Experiments for integrated agriculture-aquaculture system design. In: Prein, M., J.K. Ofori and C. Lightfoot (eds.) Research for the Future Development of Aquaculture in Ghana. ICLARM Conference Proceedings 42, ICLARM, Manila, 37-41

Osei-Owusu, A. (1981) Survey of wild food plants in a Ghanaian village. Project Paper. Institute of Renewable Natural Resources, University of Science and Technology, Kumasi.

Pullin, R.S.V. (1989) Third-World Aquaculture and the Environment. NAGA, The ICLARM Quarterly, Jan.:10-13.

ROG (Republic of Ghana) Ministry of Health. (1986) National nutrition survey, 1986. Accra, Ministry of Health.

ROG (Republic of Ghana) Ministry of Agriculture. (1987) Performance of the agricultural sector, 1987. Policy Planning Monitoring and Evaluation Department, Ministry of Agriculture, Accra.

ROG (Republic of Ghana) Statistical Service. (1989) Ghana living standards survey. First year report, September 1987-August 1988. Accra, Republic of Ghana Statistical Service.

ROG (Republic of Ghana) Statistical Service.(1989)Quarterly digest of statistics 3(1). Accra, Republic of Ghana Statistical Service.

ROG (Republic of Ghana) Statistical Service.(1990) Quarterly digest of statistics 8(3) September. Accra, Republic of Ghana Statistical Service.

ROG-IRD (Republic of Ghana, Ghana Statistical Service and Institute for Resource Development). (1989) Ghana: Demographic and Health Survey 1988. Ghana Statistical Service and Institute for Resource Development/Macro Systems Inc., Accra and Columbia, Maryland.

ROG (Republic of Ghana) and UNICEF (United Nations Children's Fund.(1990) Children and Women of Ghana: A situational analysis 1989-90. Accra, ROG-UNICEF.

Ruddle, K. (1994) Some adaptive strategies and natural resource uses in tropical wetlands (Southeast Asia) In B.C.Patten (ed.) Wetlands and shallow continental water bodies. The Hague, SPB Academic Publishing, 535-573.

Ruddle, K. (1996) The Potential Role Of Integrated Systems Of Agriculture-Aquaculture In Improving The Nutritional And Economic Status Of Resource-Poor Farm Households In Ghana. In: Prein, M., J.K. Ofori and C. Lightfoot (eds.) Research for the Future Development of Aquaculture in Ghana. ICLARM Conference Proceedings 42, ICLARM, Manila, 57-85.

Ruddle, K. and G. Zhong.(1988) Integrated agriculture-aquaculture in South China: the dike-pond system of the Zhujiang Delta. Cambridge University Press, Cambridge.

Schroeder,G.L.(1980) Fish Farming in Manure-loaded ponds. In R.S.V. Pullin and Z.H.Shehadeh (eds.). Integrated agriculture-aquaculture. ICLARM, Manila, 73-86.

Sefa-Deddeh, S. (1981) Protein utilization in Africa. In: Stanley, D.W., E.D. Murray D.H. and Lees (eds.), Utilization of protein resources. Food and Nutrition Press Inc, Westport, Conn., 32-72.

Watson, J.D. (1971) Investigations on the nutritive value of some Ghanaian foodstuffs. Ghana Journal of Agricultural Science 4:95-111.

Whitby, P. (1968) Foods of Ghana. Food Research and Development Unit, FAO, Accra.

Woodhouse, P. (1989) From green revolution to food security in sub-Saharan Africa: issues in research and technology development, Food Policy (Feb.): 7-12.

NOTES AND ACKNOWLEDGMENT

This study was conducted under the ICLARM/ GTZ-FD-UM Project, "Research for the Development of Tropical Aquaculture Technology Appropriate for Implementation in Rural Africa".

[1] Systems of aquaculture may be classified in various ways. That of most practical value for the comparative assessment of the feasibility of aquaculture development, its sustainability, and impact on the natural and socio-economic environment is based on the intensity of inputs to systems (Pullin, 1989). In these terms, three categories of system can be defined: *extensive*, which have no feed or fertilizer inputs; *semi-intensive*, with some feed and/or fertilizer inputs; and *intensive*, that depend mostly on external feed and/or fertilizer inputs.

[2] In contrast, "formal" irrigation systems are based on high-capitalized, large-scale engineering, and are centrally managed.