Background Paper 2

Bioenergy

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The Multifunctional Character of Agriculture and Land: the energy function.
Background Paper 2: Bioenergy.

1. BIOMASS ENERGY

Biomass currently supplies about a third of energy in developing countries. Precise levels vary from about 90% in countries such as Nepal, Rwanda, Tanzania and Uganda, to 45% in India, 28% in China and Brazil. Levels are lower in industrial countries; 14% in Austria for example, 20% in Finland and 18% in Sweden. On a global basis, biomass contributes about 14% of the world's energy (55EJ or 25 M barrels oil equivalent, offsetting 1.1 PgC of net CO_2 emissions annually) (See Fig. 1). The most pressing questions concern whether the two billion or more people who are now dependent on biomass for energy will actually decrease in numbers in the next century and what are the future consequences to development and environment (local and global) from this continuing dependence on biomass. The World Bank (1996) recognised that "energy policies will need to be as concerned about the supply and use of biofuels as they are about modern fuels".

Bioresources are potentially the world's largest and sustainable source of fuel and chemicals- a renewable resource comprising 220 billion oven-dry tonnes (about 4,500 EJ) of annual primary production. Estimates of the total annual amount of biomass are about 2×10^{11} tonnes of organic matter, which is equivalent to about 4×10^{21} J of energy. The energy content of biomass on the earth's surface is the equivalent to about 36×10^{21} J (Hall & Rao, 1999). However, the average coefficient of utilization of the incident photosynthesis active radiation by the entire flora of the earth is only about 0.27%.

Residues represent a large potential of readily available energy which is mainly under-utilised at present, although it is difficult to provide any reliable figures. The energy content of potentially harvestable residues (the total residues produced that could potentially be defined as collectable) is about 93 EJ/yr worldwide. Assuming that only 25% of this is realistically recoverable, residues could provide 7% of the world's energy (Woods & Hall, 1994).

It is evident that the problem is not one of availability but relates to the sustainable management and delivery of energy to those who need it at an acceptable cost.

Bioenergy is increasingly being used as a modern energy carrier in many industrial countries. It represents about 4% of the primary energy use in both the EU and USA. In the EU this is equivalent to 2 EJ/year of the estimated total consumption 54 EJ. Estimates show a likely potential in Europe in 2050 of 9.0-13.5 EJ depending on land areas, yields, and recoverable residues, representing about 17-30% of projected total energy requirements.

It is now increasingly realised that there is considerable potential for the modernisation of biomass fuels to produce convenient energy carriers such as electricity, gases and transportation fuels whilst continuing to provide for traditional uses of biomass. The modernisation of biomass and the necessary industrial investment is already happening in many countries. However, it is important to emphasise that the future use of bioenergy must be strongly linked to high energy efficiency, and environmentally sustainable production and use.

1.1 Trends in per capita total biomass use.

There has been considerable discussion as to whether current bioenergy use is actually decreasing in real and absolute terms. Attempts to determine biomass energy use “per capita” have been compounded by a large number of difficulties and thus estimates vary considerably. These difficulties include: i) lack of long-term quantitative data on biomass use; ii) good data is usually based of small-scale and site-specific examples thereby making extrapolation difficult; iii) biomass energy has often been regarded as the poor man’s fuel and little attention has been paid to statistical data and as a result there is a lack of long-term historical data on which to base long-term projections; iv) biomass energy use is influenced by factors such as climate, land use patterns, income distribution, cultural factors, cooking techniques and reliability of supply; v) lack of uniform definitions, conversion factors, and methodologies which make comparisons difficult and unreliable; vi) low prestige attached to traditional biomass energy by policy makers and energy planners; vii) the widely held belief that biomass was primarily a transitory energy solution in rural areas; viii) biomass was not considered as an energy source with potential for modern and commercial possibilities.

Policy-related decision-making on biomass energy has been hampered by these constraints which has resulted in a serious inability to assess indigenous resource capability and its real potential contribution to development. Lack of reliable data often led to controversial interpretations of the bioenergy situation and to erroneous policy decisions. It has been only recently that serious attempts have been made to overcome these shortcomings by agencies such as FAO and IEA.

The conventional view that biomass energy consumption decreases proportionally as income per capita increases is questionable. The picture appears to be more complex since biomass energy use is influenced by a large number of factors including: i) a large decline in some of the most traditional forms of biomass in many developing countries as income per capita increases e.g. substitution of cow dung for fuelwood in India, and straw in China; ii) an increase in the quality of the biomass resource with increasing urbanisation and living standards, such as the use of charcoal in urban areas, institutions and industry in many countries in Sub-Saharan Africa and South-East Asia; iii) a rapid increase of modern applications of biomass energy in high income countries such as Austria, Finland, Denmark, Sweden and USA. In industrialised countries the main reasons for recovered biomass use seem to be: a) environmental awareness, b) deliberate choice of consumers who have the income and willingness to pay higher prices for biomass-based energy, c) availability of resources, and d) government policies that favour the introduction of renewable energy.

It is estimated that biomass consumption in all its forms in rural areas of developing countries (including all types of biomass and end-uses) is about 1 tonne (20% moisture, 15GJ/t) per person per year and about 0.50 tonne in periurban and urban areas (Hall & Rosillo-Calle, 1998). FAO data shows that the estimated consumption of wood energy alone per capita in developing countries is about 0.25 tonnes oil equivalent (toe, equal to 10 GJ) and that of industrialised countries 0.2 toe which seems a conservative figure. FAO estimates of worldwide wood energy use alone (used directly as fuelwood) in 1990 was 1,800 M m^3, plus

300 M m^3 of residues from the manufacture of wood products (520 M toe, or 22EJ) and 2,400 M m^3 in 2010 (FAO, 1996a), IEA (1998) estimate is 45 EJ.

Thus, the present trends in biomass energy use can thus be summarised as follows: i) overall, biomass energy use remains stable, or even increasing in absolute terms, due to population growth in developing countries and increased use in the industrialised countries. There are, however, many variations due to the large numbers of factors involved ranging from availability of supply, climate, socioeconomic development, cultural factors, etc.; ii) an increase in modern applications and a gradual shift away from the most primitive uses of energy (e.g. the use of dung and straw for cooking); iii) greater efficiency of resources through, for example improved cooking stoves; iv) more positive policy-maker attitudes towards biomass energy both in its traditional and modern forms.

1.2 The agricultural role: past and present.

The role of agriculture in energy production is lost in history. From early hunter-gathering to annual agriculture plant products provided human food, fuel, fodder, building material, etc. Biomass was the main source of energy up to the early 20th century. The diverse use of biomass utilization is well represented in the so-called six Fs: “food, fuel, feed, feedstock, fibre, and fertiliser”. In the case of fuel production, in the past few decades this has not received the deserved attention as this reality was largely ignored or under recognised by policy makers and energy planners alike.

The role of agriculture in food and energy production needs to be re-evaluated. Population growth and environmental pressures require a new paradigm to ensure sustainability. Global agricultural practices vary enormously ranging from very high inputs (energy intensive, machinery, capital, chemical fertilisers, etc) in the industrialised countries, to almost primitive forms in many rural areas of developing countries.

The world is facing an increasing challenge of how to feed, house, educate, and employ a growing number of people particularly in developing countries. To meet these basic needs significant economic, social and political changes are required if serious and irreparable environment damage is to be avoided. As Reddy (1998) puts it, “the point is that the present pattern of resource use has posed serious environmental problems and we do not have acquired scientific data to understand and analyse them in order to arrive at a solution. Given the lack of consensus on a common methodology, we have to focus on these environmental problems from various perspectives which deal with values and beliefs, lifestyles, technologies, governmental policies, and non-governmental institutions.”

Adequate food supplies and reasonable quality of life require energy both in commercial and noncommercial forms; in developing countries the latter is the most important, particularly in rural areas. The economy of many developing countries relies on agriculture where most of the work is often done using primitive tools and working practices that have seen little change for decades. Food can be produced with very little or no fossil fuel energy, e.g. using slash-and-burn agriculture. For example, FAO statistics show that human effort provides over 70% of the energy required for crop production in many poor countries. However, population, environmental, economic and particularly social equity pressures frequently makes this option unsustainable.

2. BIOENERGY AND THE ROLE OF AGRICULTURE IN THE INTERNATIONAL ENERGY SCENARIO.

Energy is a core component for achieving higher agricultural productivity and alleviating poverty. Without modern energy inputs, agriculture will have to rely on human power that translates into human drudgery, low productivity and extensive agriculture. On the other hand, there is growing awareness of the many implications and problems caused by high energy inputs in modern agriculture, such as resource depletion, unsustainability and pollution. There is a need for better understanding of the energy-agriculture links and the potential for sustainable energy systems based on renewable energy sources, in particular, biomass. Thus, greater emphasis should be given to: i) evaluation of the energy-agriculture interrelationships for different systems; ii) better understanding of the integrated management of energy and other inputs e.g. water, fertilisers, etc, and iii) assessment of the potential of biofuels for different environmental and land-used policy situations (FAO, 1996a). It could be concluded that the production and use of bioenergy in its modern forms can have a major and positive impact on agricultural development.

The growing interest in bioenergy is reflected in the large number of energy scenarios published in the past decade or so, most of which include a significant role for biomass energy in the energy matrix of the future and thus has potential implications for agriculture. Eight of these scenarios are summarised below (see Table 1 for a brief overview and main references) (Hall, House & Scrase, 1999).

1. The Renewables - Intensive Global Energy Scenario (RIGES) prepared as part of the UNCED Rio de Janeiro Conference in 1992 proposes a significant role for biomass in the next century. This proposal is that by 2050, renewable sources of energy could account for three-fifths of the world's electricity market and two-fifths of the market for fuels used directly, and that global CO_2 emissions would be reduced to 75% of their 1985 levels. Such benefits could be achieved at no additional cost. Within this scenario biomass should provide about 38% of the direct fuel and 17% of the electricity use in the world.

2. The Environmentally Compatible Energy Scenario (ECES) for 2020 assumes that past trends of technological and economic structural change will continue to prevail in the future and thereby serve, to some extent, economic and environmental objectives simultaneously. Primary energy supply is predicted to be 12.7 Gtoe of which biomass energy would contribute 11.6% (62 EJ) derived from wastes and residues, energy plantations and crops, and forests - this excludes traditional uses of non-commercial biomass energy in developing countries.

3. A Fossil-Free Energy Scenario (FFES) was developed as part of Greenpeace International's study of global energy warming, and forecasts that in 2030 biomass could supply 24% (=91 EJ) of primary energy supply out of a total of 384 EJ.

4. The World Energy Council (WEC) examined four “Cases” for global energy supply to 2020 spanning energy demand from a “low” (ecologically driven) case of 475 EJ to a “very high” case of 722 EJ, with a “reference” case total of 563 EJ. In the ecologically - driven case traditional biomass could contribute about 9% of total supply while modern biomass would supply 5% of the total equal to 24 EJ or 561 Mtoe.

5. Shell International Petroleum Company carried out a scenario analysis of what might be the major new sources of energy after 2020, when renewable energies have progressed

along their learning curves and become competitive with fossil fuels. After 2020, in their business-as-usual scenario, the renewables biomass, wind, solar and geothermal become the major new suppliers of energy. In their conservation scenario where less new energy is needed, biomass becomes the major supplier, with smaller roles for the other renewables.

In the business-as-usual (Sustained Growth) scenario total global energy use in 2060 amounts to over 1500 EJ (compared to 400 EJ today), of which biomass provides 221 EJ (14% of the total), with 179 EJ coming from plantations rather than traditional non-traded sources. Solar and wind would provide 260 and 173 EJ, respectively. In the conservation (Dematerialisation) scenario total energy use in 2060 amounts to under 940 EJ, with fossil fuels and nuclear providing 41% of the total; biomass provides 207 EJ (22% of the total), with 157 EJ from dedicated bioenergy sources. Shell have recently set up Shell International Renewables as part of their core business, and will invest US$500 million in biomass and solar energy over the next 5 years.

6. The Intergovernmental Panel on Climate Change (IPCC) has considered a range of options for mitigating climate change, and increased use of biomass for energy features in all of its scenarios. In their five scenarios biomass takes an increasing share of total energy over the next century, rising to 25 - 46% in 2100. In the biomass intensive energy scenario, with biomass providing for 46% of total energy in 2100, the target of stabilising CO_2 in the atmosphere at present-day levels is approached. Annual CO_2 emissions fall from 6.2 GtC in 1990 to 5.9 GtC in 2025 and to 1.8 GtC in 2100: this results in cumulative emissions of 448 GtC between 1990 and 2100, compared to 1300 GtC in their business-as-usual case.

7. The IIASA/WEC (1998) study “Global Energy Perspectives” examined three main scenarios – Case A High Growth; Case B Middle Course; Case C Ecologically Driven. Within Case A, three sub-scenarios were envisaged: Case A1 with oil and gas, Case A2 with coal, and Case A3 with biomass and nuclear. In scenario A3 biomass could contribute nearly 17% (316EJ) of total energy by 2100 and in Scenario C1 (renewables and no nuclear) biomass provides nearly 30% (245EJ) of a lower total energy (878EJ for C1 and 1855EJ for A3).

8. In the IEA (1998) study “World Energy Outlook” addressed for the first time in its biannual “Outlooks” the current role of biomass energy and its future potential. It is estimated that by 2020 biomass will be contributing 60EJ (compared to their estimate of 44EJ today = 11% of total energy) thereby providing 9.5% of total energy supply. The period 1995-2020 will show a 1.2% annual growth rate in biomass provision compared to a 2.0% rate for “conventional” energy.

From the above studies the biomass contribution ranges from 59 to 145 EJ in 2025 and 94 to 220 EJ in 2050. This compares to present total consumption of about 400 EJ of which about 55 EJ comes from biomass. The large role biomass is expected to play in future energy supply can be explained by several considerations, with major implications for agriculture. Firstly, biomass fuels can substitute more-or-less directly for fossil fuels in the existing energy supply infrastructure. Secondly, the potential (see section 1) resource is large since land is available which is not needed for food production and as agricultural food yields continue to rise in excess of the rate of population growth. Thirdly, in developing countries, demand for energy is rising rapidly due to population increase, urbanisation and rising living standards (Hall, House & Scrase, 1999).

Forecasting future energy demand and supply is notoriously difficult and imprecise, but what is evident from examining all these scenarios is that biomass could be a major contributor to future energy supplies especially as a modern fuel, while still playing an important role as a traditional fuel i.e., **a combined traditional and modern role**. How much bioenergy will contribute in the next century will depend on many factors all of which are difficult to foresee at this stage.

However, if bioenergy, particularly as a modern energy carrier, becomes a major source of energy, it could have a profound influence in many rural areas of developing countries; it could **speed up socio-economic development as a large number of farmers could increase food production and their own energy in an sustainable manner.** This could be done through efficient use of residues and combined agriculture-energy crop systems.

3. THE ROLE OF AGRICULTURE IN ENERGY CONSUMPTION, PRODUCTION, AND CO2 MITIGATION.

Despite the high energy intensity of agriculture in industrialised countries, fossil energy use in agriculture is only about 3-4% (although estimates vary) of the total consumption, and an even smaller fraction in the developing countries. Thus in global terms, energy consumption in agriculture is small and thus not an area which offers a large potential for mitigation. During the 1970s, there was a considerable concern with energy use in agriculture and large number of studies were carried out to assess this energy use (FAO 1979; Pimentel 1980; Stout, 1990). Currently this interest has subsided to the point were research funding for energy in agriculture has almost disappeared. Under the new environmental and social international agendas, including the impetus given by the UN Conventions on Biodiversity, Climate Change and Combatting Desertification, interest should increasingly focus on the energy/agriculture linkages, and on a more methodological approach to the "energy and food production chain system".

Human civilisation, as we know it, would be impossible without considerable additional use of energy beyond the work capacity of humans. Current agricultural production would have been impossible without additional energy through machinery, fertiliser, water pumping, ploughing, etc., all of which require modern use of energy. This additional energy is driving our modern society. It is also important to bear in mind the potential of biomass to provide multiple local, regional and global benefits, in addition to sustainable energy: it is a long term entrepreneurial opportunity for improved land management based on optimal productivity using minimum inputs of resources while producing environmental and social benefits.

Tillage, use of fertilisers, and planting and harvest operations offer a high potential for C emission mitigation through technical improvements. For example, the fixation of atmospheric N into synthetic fertiliser requires energy (usually from fossil fuels); the energy required to produce 1 unit of N in fertiliser emits 1.5 units of C to the atmosphere. Thus it is estimated that the global consumption of about 80 Tg (80 Mt) of fertiliser N results in the emission of 120 Tg (120 Mt) C (Cole et al. 1996). Because of the expected increase in fertiliser use in developing countries, total consumption could double in the next 25 years. It is clear that optimising N use efficiency and minimising N surpluses could help to mitigate emissions of CO_2, in addition to gases such as N_2O.

Of the various strategies put forward for CO_2 sequestration and substitution, the use of biomass energy as a direct substitute for fossil fuels offers the greater potential, and which is of particular relevance to agriculture. This strategy can be achieved in various ways: i) by increasing the land area dedicated to bioenergy production either from existing or abandoned agricultural land; ii) better use of agro-forestry residues; iii) increased efficiency of biomass-based conversion processes, and iv) integrated food-energy production.

The experience with energy crops is still very limited and most of what it is known owes more to traditional agricultural techniques that anything else. Nonetheless the use of dedicated energy forestry/crops is increasing rapidly: Brazil’s ethanol from sugarcane program and charcoal from plantations; USA’s ethanol from maize; and Sweden’s willow plantations. Some studies have indicated that the potential replacement of fossil fuel by energy crops in the tropics alone can be as high as 150 to 510 Tg (150-510 Mt) C/yr. In the temperate zones, C offsets could potentially reached 80 to 490 Tg C/yr. Agroforestry systems, where trees are grown in managed combinations with food or feed, could offset 10 to 50 Tg C/yr and between 50 to 200 Tg C/yr in tropical regions (Sampson et al, 1993; Paustian et al. 1998). Table 2 summarises the global mitigation potential of CO_2 from agriculture.

Estimating biomass energy potential and its implications for agriculture is rather complicated because of the many variables involved ranging over crop productivity, land availability, harvesting and transportation, conversion efficiencies and substitution factors. Nonetheless, Table 3 presents an estimate of the bioenergy potential to offset CO_2. The table represents an attempt to estimate the primary energy that could be substituted over the next few decades as a result of agricultural biomass production. Overall, energy forestry/crops and crop residues have the potential to substitute for 0.5 to 1.6 Pg fossil fuel C/yr, or about 8-27% of the current global consumption of fossil fuels (Paustian et al, 1998).

Large amounts of C could also be sequestered in soils (24-43 Pg over a 50 year period) through improved management of agricultural land, permanent set-aside land, and restoration of degraded lands. **Of all the options, direct substitution of fossil fuels by bioenergy, represents the largest and most sustainable alternative, representing a “win-win” situation (Paustian et al, 1998).**

3.1 The technical dimension – including new paths

Agriculture in industrialised countries is characterised by high inputs in terms of machinery, energy (fossil energy), capital, etc. In most developing countries the main feature is low energy input through the predominant use of traditional low-energy input techniques, human and animal power and low fertiliser use. Technological advances in agriculture, although intertwined, could fall into two broad categories: i) those aimed specifically at reducing negative environmental effects and, ii) those aimed at increasing productivity, trade liberalisation, commercial opportunities, socio-economic development, equity, etc.

There are many opportunities for ameliorating negative environmental effects of energy use in agriculture. Options include: increasing the use of organic fertilisers and manure management; increasing C soil sequestration by improved management and cultivation techniques; and encouraging policy measures that promote sustainable agricultural systems. A common feature of many of these measures is that their primary objectives are often not related solely to climate change issues but rather to other more specific goals such as control of soil erosion, organic agriculture, pollution control, trade liberalisation, etc.

Agricultural technologies that boost yields such as improved varieties and management techniques, have not been yet adopted by many rural farmers and could increase yields by

50% worldwide. A major priority in the future must be to ensure that these technologies reach all those farmers. Africa currently only uses a fifth of its potential cropland, and would still have 75% remaining in 2025 on which it could theoretically produce nearly 10 times its present energy consumption. Latin America, presently using only 15% of its potential cropland and would still have 77%, according to FAO data.

A recent FAO study has recognised that "there appear to be no insurmountable resource and technology constraints at the global level that would stand in the way of increasing world food supplies by as much as required by the growth of effective demand. And, on balance, there is scope for such growth in production to be achieved while taking measures to shift agriculture on to a more sustainable production path" (FAO, 1996a p32).

For climate-friendly technologies to be available in the long term requires climate-friendly choices. The challenge to politicians is to put in place policy frameworks- on a timescale far beyond that which is usual in politics- that will stimulate these choices. Currently, especially in industrial countries, there is growing cooperation on a whole range of energy policy and technology issues, often referred to as the "3Es": <u>e</u>conomic development, <u>e</u>nergy security, and <u>e</u>nvironmental protection. To achieve sustainable development it is necessary to reconcile these 3Es (Priddle, 1999).

Technical breakthroughs have already contributed significantly to both food production and emissions reductions. New technology initiatives are underway that will assist in this matter further e.g. the IEA's new energy efficiency measures aimed at reducing so-called "Leaking Electricity", and a clearing house for international dissemination of energy-technology information.

A recent USDOE study pointed out that "advanced biological processes will be developed and deployed to enable practices to sequester C in natural systems, remove or convert C from fossil energy systems into useful and refractory products, and recycle C through biological processes into end products that substitute for fossil C sources" (USDOE, 1999).

An important feature of current technology for the capture and separation of combustion sources with low concentration CO_2 streams, is high energy costs. A novel idea is to jointly produce energy and capture C and thereby result in significantly lower costs. This may be achieved in the so-called "energycomplexes" with the integration of biological processes. Biological processes integrated into energycomplexes would produce energy, treat waste, sequester carbon, and produce useful products. For example, the integration at one site would minimise transportation costs, minimise the potential for environmental damage, and maximise yields (USDOE,1999).

> "The energycomplex concept involves recycling CO_2 in waste flue gas from a power generation facility via photosynthesis to generate and store reduced carbon in the form of algal biomass. Storage can take the form of polysaccharides or triglycerides, both of which are readily usable fuels, or of chemical feedstocks for downstream bioconversion processes" (USDOE, 1999).

However, the greatest C emissions reduction potential are from forestry/energy crops. This will only be a reality when the economic and political conditions lead to <u>large scale use of these crops for direct substitution of fossil fuels</u>. For this to occur, important changes must take place in areas such as subsidies reform, land reform, equity rights, rural finance and marketing.

4. ENERGY CROPS AND RESIDUES.

Residues are a large and under-exploited potential energy resource, and thus represent many opportunities for better utilization for energy purposes. However, there a number of important factors that need to be addressed when considering improved use of residues for energy. Firstly, there are many other alternative uses of residues e.g. feed, their role in reducing erosion, stabilisation of soil structure, enhance moisture content, use as animal bedding or use as fertilisers (dung). Secondly, the problem of agreeing on a common methodology for determining what is and what is not a recoverable residue. Estimates often vary by a factor of five. This is due, among other things, to variation in the amount of residue assumed necessary for maintaining soil organic, soil erosion control, efficiency in harvesting, losses, non- energy uses, etc.

Given that residues may remain more widely used than energy crops for quite some time, guidelines are urgently needed as to when it is appropriate to use residues for energy, what fraction can be used, and how best to maximise the environmental advantages this may offer. This has already largely been done for the energy forestry/crops, but is still lacking for residues.

4.1 Agricultural residues

For the reasons explained above, it is necessary to remain cautious when dealing with agricultural residues, despite the many attempts carried out to estimate the energy potential of such residues. For example, Smil (1999) has calculated that in the mid 1990s the amount of crop residues was between 3.5 to 4 Gt annually, with an energy content representing 65 EJ, or 1.5 Gt oil equivalent. On the other hand, Hall et al (1993) have estimated that using the world's major crops only (e.g. wheat, rice, maize, barley, and sugarcane), a 25% residue recovery rate could generate 38 EJ and offset between 350 to 460 Tg C/yr (Table 4). There is no doubt that a large part of the residues are wasted, handled inappropriately causing undesirable effects from the environmental, ecological and food production viewpoints. For example, Andreae (1991) has estimated that over 2 Gt of agricultural residues are burned annually worldwide, while Smil (1999) estimates are between 1.0 and 1.4 Gt, producing 1.1 and 1.7 Gt/yr of CO_2. Paustian et al, (1998) have estimated that crops residues could offset 220 to 320 Tg C based on assumptions for energy conversion and degree of substitution for fossil carbon.

4.2 Energy crops

It is difficult to predict at this stage what will be the future role of specifically grown biomass for energy purposes. This is, in many ways, a new concept for the farmer which has got to be fully accepted if large scale energy crops are to form an integral part of farming practices. Hall et al (1993) have estimated that as much 267 EJ/yr could be produced from biomass plantations alone

Currently there are in the world about 100 Mha of plantations. During the past decade about 40 Mha have been planted in developing countries, two-thirds in community woodlots, farms and small holdings, to provide industrial wood, environmental protection and energy. In the USA some 50,000 ha of agricultural land has been converted to woody plantations and in Sweden about 18,000 ha of willows for energy purposes.

It is clear that management practices are a key factor in sustainable biomass production and use. While it is possible to provide considerable data on traditional forms of management practices, particularly in the pulp/paper and cellulose industry, by comparison relatively little is still known with regard to large-scale energy forest plantations or even agricultural and forestry residues for energy use. Thus little experience now exists with large-scale energy plantations, except for Eucalyptus for charcoal production and ethanol from sugarcane in Brazil (which in any case tend to follow traditional agricultural and forestry practices), and also willows for heat and power generation in Sweden - this program also borrowed considerably from traditional forestry and agricultural activities.

There is a growing concern with the potential negative effects of large scale dedicated energy crops/forestry plantations. As a result, in recent years, a considerable amount of effort has gone to address these concerns which has resulted in the development of some "good practice guidelines" for the production and use of biomass for energy in , for example, Austria, Sweden, UK and USA. These guidelines recognise the central importance of site-specific factors, and the breadth of social and environmental issues which should be taken into consideration. The guidelines concentrate mostly on short rotation coppice, and in some cases, like in the USA guidelines, also consider perennial grasses and some residues.

A key message is that site and energy crop selection must be made carefully, and the crop must be managed sensitively. Energy crops should not displace land uses of high agricultural and ecological value. Consideration must be given to: (Hall, House & Scrase, 1999).

- consulting local people at the early planning stage;
- biodiversity;
- landscape and visibility;
- soil type;
- water use;
- vehicle access
- nature conservation;
- pests and diseases;
- public access.

There is no single best way to use biomass for energy, and environmental acceptability will depend on sensitive and well informed approaches to new developments in each location. It is clear that biomass for energy can be environmentally friendly, and steps must be taken to ensure that it is, if biomass is to be accepted as an important fuel of the future, and the implications for the agricultural sector thoroughly assessed.

4.3 Forestry residues

Forestry residues obtained from sound forest management do not deplete the resource base. Through sustainable management practices, trees are replanted and/or the forest resource is managed for regeneration to enhance its health and future productivity. Energy can be thought of as just one of the many outputs of forests. Depending on their nature and intensity, forest management practices can increase some forest outputs while decreasing others, e.g., energy in preference to pulp and paper. One of the difficulties is to estimate, with some degree of accuracy, the potential of residues that can be available for energy use on a national or regional basis, without more data on total standing biomass, plantation density, thinning and pruning practices, current use of residues, MAI, etc.

Recoverable residues from forests have been estimated to have an energy potential of about 35 EJ/yr (Table 4). A considerable advantage of these residues is that large part are generated by the pulp and paper and saw mill industries and thus could be readily available. Currently a large proportion of such residues are used to generate energy in these industries, but there is no question that the potential is much greater.

4.4 Livestock residues

The potential of energy from dung alone has been estimated at about 20 EJ worldwide (Table 4). However, the variations are so large that figures are often meaningless. These variations can be attributed to a lack of a common methodology which is the consequence of variations in livestock type, location, feeding conditions, etc.

Despite this large potential it is questionable whether animal manure should be used as an energy source on a large scale, except in specific circumstances. This is because: i) its greater potential value for non-energy purposes such as fertiliser, which may bring greater benefits to the farmer, ii) it is a poor fuel and people tend to shift to other better quality biofuels whenever possible, iii) the use of manure may be more acceptable when there are other environmental benefits; this is the case of production of biogas in Denmark, because of large surpluses of manure which, if applied in large quantities to the soil, represent a danger for agriculture and the environment. It is important to remember that biogas programmes in China and, to some extent in India, Nepal and Vietnam, have provided important contributions to energy, sanitation and fertiliser needs. This field of work has been extensively reported on by agencies such as FAO and GTZ and by Governmental Reports from China and India.

5. ENVIRONMENTAL, HEALTH AND SOCIO-ECONOMIC ASPECTS

5.1. Environment.

In recent past there has been a significant environmental shift as the consequence of: i) public pressures, particularly in the industrialised countries; ii) surplus agricultural lands in the EU and USA; iii) scientific and technological progress, such as a greater understanding of the risks to humans and ecosystems of certain practices, and iv) the development of cleaner and more efficient energy technologies. These pressures will continue which, in the case of agriculture, will lead to further calls for sustainability.

It is only in the last decade or so that increasing concentrations of CO_2 in the atmosphere have been considered to present a serious environmental problem. Historically we have developed an intricate, tightly coupled energy system that has been optimised over 200 years for economy and efficiency, but not for the capture and sequestration of CO_2. This also has major repercussions for agriculture. However, with the increased use of bioenergy, particularly in its modern forms, this situation could change significantly.

Traditionally biomass energy has often been associated with environmental degradation and health hazards with also implications for agricultural practices. These are complex and interrelated socioeconomic and cultural issues. This view was particularly prevalent in the 1960s and 1970s when the premise was that large-scale deforestation arose as consequence of overcutting of forests for fuelwood. The facts indicate that overcutting was usually a secondary consequence of a more general failure to care for diminishing forest lands and resources. Recent evidence shows that much of the fuelwood and charcoal was obtained not from forests but clearing for agriculture land and from scattered trees on farms, roadsides, etc (FAO, 1996b). In Brazil deforestation was caused mainly by the expansion of agricultural and pasture land.

However, there is no doubt that biomass energy, particularly in its traditional forms, can cause serious environmental and health impacts due to low energy efficiency and to the exposure to many pollutants such as respirable suspended particulates, carbon monoxide, organic compounds, etc. This is the result of complex socio-economic and cultural factors which will have to be addressed if such negative effects are to be ameliorated. Many of these impacts could be significantly reduced by introducing more efficient technologies, improved ventilation, improved stoves for cooking and heating, changes in cooking practices, use of better quality fuels (fuelwood rather than dung and straw), and better education on the health implications of such exposure. Thus, policies are needed that support this modernisation drive (Smith, 1996; Hall and Rosillo-Calle, 1999).

There are a wide number of potential measures and policy instruments which could be applied to agriculture to reduce Greenhouse Gases (GHG) emissions ranging from economic instruments such as taxes, to regulatory measures, R&D, etc. Table 5 provides a summary of some of the main policy instruments and measurers that can influence GHG emissions in agriculture. C sequestration in agriculture may be achieved in various ways: i) increasing photosynthetic C fixation, ii) reducing decomposition of organic matter, iii) reversing land use changes, such as deforestation, that contribute to global emissions and iv) creating energy offsets through the use of biomass energy and other products. The last two methods may be more appropriately called “C management strategies”. For example, it is estimated that with 10 to 15% of the land dedicated to energy crops, between 0.5 and 0.8 GtC/yr C offset could be achieved, in addition to many other benefits. Present day examples are bioethanol for transport and cogeneration from sugarcane bagasse. Direct substitution of fossil fuels by biomass is the option which seems the more suitable and less costly (in particular when afforestation is undertaken), than C sequestration alone.

Simply sequestering carbon in new forests is problematic and is not a long term solution because trees cease sequestering once they reach maturity, and as available land is used up (and emission from fossil fuels continue), the cost of further afforestation will grow. Indeed the cost of removing GHG from the atmosphere is often lower for fossil fuel substitution than for C sequestration, since fast growing energy crops are more efficient at carbon removal, and because revenue is generated by the sale of electricity.

5.1.1 The implications of the Kyoto Protocol (KP).

The Kyoto Protocol, result of the United Nations Framework Convention on Climate Change, is designed to provide binding, quantitative limits on future net emissions of greenhouse gases to the atmosphere. If the objectives of GHG emissions reduction were to be achieved, there would be important implications for the energy sector in general and biomass energy in particular. Despite the many shortcomings, the Protocol requires a cut in CO_2 emissions by 6% below the 1990 level over the period 2008-2012. Considering that industrial countries already produce CO_2 about 13% above the 1990 level, CO_2 would have to be cut by as much as 45% if trends continue unchanged. This represents major changes in the way energy is produced and used.

What could be the likely consequences of the KP for agriculture and bioenergy development?. This will be determined by the extent to which the Protocol is implemented and to the recognition that it gives to bioenergy as a source for C mitigation. It seems that the KP failed to fully recognise this role and has put considerably more weight on forests as a source of C sequestration. More emphasis should be given to carbon substitution opportunities through bioenergy and, for that sake, through all forms of renewable energy sources, including solar, wind, hydro, geothermal and ocean energies. This shortcoming should be addressed.

5.2 Socio-economics.

Speed of communications is undoubtedly having a major effect on social and economic development. Knowledge transfer is becoming much easier. How much this affects rural areas is not the aim of this paper but changes in agricultural development have been both profound and hardly noticeable, with many rural areas of developing countries still using out of date techniques. There are many barriers, among which are poverty, land tenure, market accessibility and so forth, which have to be tackled. Governments in developing countries have often ignored the plight of the farming community in favour of industrialisation and urbanites, but are gradually awakening to the fact that agriculture often continues to be the main source of livelihood for the majority of the population.

In designing energy and agriculture programmes and projects, it is essential to consider the three major changes concerning the identification of farmers' needs: i) contrary to earlier views, farmers are profit maximising and accept changes providing that the technologies are not too risky and lead to profit in the short term; ii) population pressure on resources and development and adoption of technologies also depend on access to land and market incentives; iii) there is growing recognition that farmers' decision processes are weighted more by profitability than by their environmental friendliness because of the additional costs involved by the farmer (FAO 1996a).

With regard to research some new trends can be identified: i) greater emphasis on farming systems research that involves the farmer more directly in the decision-making process; ii) introduction of on-farm client-oriented research or on-farm research which is more appropriate to meet the resource-poor farming community; iii) greater acceptance of "indigenous technical knowledge", refined by farmers over many years which can meet local conditions more effectively. Bioenergy development must take these technical trends into consideration.

A factor that has not been addressed and that could influence energy in agriculture is the external cost of energy. All economic activity, and particularly energy production, leads to external cost which accrue to third parties other than the buyer and seller. These can be environmental (pollution damage to crops) or non-environmental (direct subsidies, national security of energy supply, R&D costs, goods and services publicly supplied). However, renewable energy sources, which produce few or no external costs and have several positive external effects, are systematically put at a disadvantage. Internalising external costs and benefits and re-allocating subsidies in a more equitable manner must become a priority if renewable energy sources are to be in a better position to compete with fossil fuels.

These external costs have largely been ignored, and it is only recently that they are beginning to be incorporated into energy planning. Some governments are trying to develop programmes to account for external costs such as taxes on emissions and incentives for cleaner fuels, but few schemes have yet been put into practice and most have met with strong opposition. For example, in the USA a total 29 States take externalities into consideration in resource planning and/or acquisition, but 22 do so only in a qualitative manner, with 5 States attempting to monazite the external costs. Focus has been almost exclusively on environmental externalities and particularly air emissions. In the EU various studies have been carried out such as ExternE and Biocosts, to examine the environmental and social costs of energy. However, in many developing countries external costs continue to be ignored and this hampers the introduction of bioenergy. Thus it is important that steps are taken to include these costs in the energy decision process.

5.2.1 Rural infrastructure support.

Rural infrastructure is more than having good roads; there are many other factors that need to be considered. There is increasing evidence and recognition that what matters for development, more than natural resources and man-made physical capital, is human capital, particularly in agriculture, together with land availability, water resources, inputs, credit facilities, market opportunities, etc. Thus, the generation and diffusion of technology and management capabilities for more intensive and modernised agriculture and supporting services become imperative (FAO, 1996a).

Modernisation of agricultural and bioenergy systems would not be effectively possible without good technical skills. Education should be more intersectoral and multdisciplinary in nature. Farmers should learn agro-energy techniques so that they can produce both food and energy effectively. Methodologies which treat energy and food production as a system should be developed and made available to farmers and to local decision makers. This “energy and food “ methodology would be also useful when assessing the application of the multifunctional character of agriculture and land.

5.2.2 Employment

Employment opportunities have been heralded as a major advantage of biomass because of the many multiplying effects which help to generate more economic activity and help strengthen the local economy, particularly in rural areas. Bioenergy is a significant source of employment and income generation for many poor people in developing countries, particularly for the landless and jobless who otherwise would have few or no means of livelihood. Evidence seems to indicate that bioenergy is very often closely and intricately interwoven with local economic and employment conditions, and hence with local, regional and even national prosperity and growth. This has also major implications for the agricultural sector of many countries.

Agriculture and forestry, together with bioenergy related activities, are the most intensive and largest source of employment according to FAO. A rough estimate of employment in the forestry sector suggests that annually about 60 million man/years are employed in the forestry sector globally i.e. 48 million in developing countries and 12 million in industrial countries. Some 20-25 million man/years annually are calculated to depend just on fuelwood collection and charcoal production in developing countries (FAO, 1996a).

For example, in the Philippines in 1992 it was estimated that some 830,000 households (530,00 gatherers, 158,000 charcoal makers and sellers, 40,000 rural traders, and 100,000 urban traders) were involved in the woodfuel trade, from gathering to retailing, covering 10% of all rural households and about 40% of their cash income (FAO, 1996b). In Brazil, the sugarcane ethanol-based industry employs about 800,000 people and the production and use of charcoal production generated about 120,000 direct jobs in 1996. Another important factor is the cost of employment creation, which is quite cheap in comparison to other industrial activities. For example, in Brazil to create a job in the sugarcane-ethanol industry in the mid 1990s required an investment of about US$ 11,000, compared to US$220,000 in the oil sector, US$91,000 in the automobile industry' US$419,400 in the metallurgical industry, $12,980 in the agricultural sectors, $11,180 in livestock, and $7,260 in afforestation activities (Rosillo-Calle& Bezzon, 1999). Much of this work represents a secondary activity of farmers. In the future agro-energy employment could be even a larger source of employment.

In the industrial countries bioenergy is also an important source of employment. Scrase (1997) found that in the EU it appears that the labour required to produce biomass fuels is approximately 4 to 10 times much greater than that needed for fossil fuels, and total direct employment (including power generation) is 3 to 4 times greater than for fossil fuel systems. Compared with nuclear energy, biomass for electricity requires approximately 15 times as much labour. These figures only consider direct employment, while many indirect jobs would be created or destroyed by a change in the energy mix.

However, estimation of the employment impacts of biomass energy, or any change in investments in the economy, is complex and uncertain because of the uncertainties with regard to the economic cost of investment in an expanded energy supply from biomass, and the impact this could have on displacing current employment. Thus, the question is whether such labour intensive activity could hamper economic development. More studies are needed to establish more clearly this relationship, but nonetheless, the evidence suggests that biomass for energy is a labour intensive sector, particularly favourable for rural development.

6. AGRICULTURE AND CLIMATE CHANGE IMPLICATIONS

The climatic change implications on agriculture are poorly understood and thus is difficult to make meaningful predictions. Uncertainty about the magnitude of the effects of global change on terrestrial ecosystems and consequent feedbacks to the atmosphere continue to impede sound planning at regional and global scales. A strategy to reduce these uncertainties must include a substantial increase in funding for large-scale long term ecosystem experiments and a careful prioritisation of research efforts. More accurate predictions of future atmospheric CO_2 are not possible without a better understanding of future fossil fuel use, CO_2 uptake by oceans, and the C balance of the terrestrial biosphere. It is against this uncertainty that policy makers must base their decisions.

A new approach to ecosystem research is needed to provide the information required to guide global change policy decision-making. Past, large-scale ecosystem research programs of the 1960s and 1970s were primarily descriptive rather than experimental, and most current experimental ecosystem research is at scales too small to address whole-ecosystem responses. Key features of such research programs must be experiments that address responses to multiple interacting environmental factors such as CO_2, temperature and precipitation. Such programs will not only require a substantial increase in funding for ecosystem research, but also a high level of coordination and cooperation among large, interdisciplinary-multisectoral research teams (USDOE, 1999).

The terrestrial ecosystem is a major biological scrubber of atmospheric CO_2 which currently represents a net C sequestration of ~ 2 GtC/yr, but it is estimated that globally it is possible to sequester ~5-10 GtC/yr which could be manipulated over the next quarter of century to provide a critical “bridging technology” while other C management options are developed.

The total amount of C stored in terrestrial ecosystems (above and below ground) is about 2000 ± 500 GtC. However, our understanding of how to sequester C on a large scale is very limited and uncertain, and thus we need: i) to take a whole ecosystem approach, which is not easy, ii) C sequestration strategies may have unforeseen consequences beyond simply increasing C storage, iii) land use and sequestration actions could also alter the flow of micronutrients (USDOE, 1999).

There are significant opportunities for mitigating CO_2 in agriculture through changes in the use and management of agriculture with the potential of converting agriculture into a net C sink. These have has not been fully explored, and merit particular attention. These opportunities fall into two broad categories: i) changes in terrestrial C stocks, primarily C stored in vegetation and soils; e.g., decreases in these stocks results in a net flux of CO_2 while increasing the standing stocks of organic C in soils and biomass removes CO_2 from the atmosphere; ii) reduction of fossil fuel consumption either as energy or other industrial uses. Agriculture consumes fossil fuel energy in various ways (all stages of the food chain, from land preparation to the use of machinery, fertilising, irrigation, transport, processing, conservation). Thus a reduction/improvement in these activities will lead to various mitigation opportunities.

Historically, agriculture has been a major source of anthropogenic GHG, at least until the 1920s . In the 1990s agriculture was responsible for about 20% of total anthropogenic CO_2, about 1.6 GtC, mainly caused by rapid land changes such as deforestation in the tropics. The current stock of C contained in the world vegetation is estimated at 550-700 Pg while soil organic C (to 1 m depth) amounts to 1400-1600 Pg. The estimated current C stock in cultivated land is 168 Pg C, excluding 54 Pg C of historical losses. The global potential for C sequestration in agricultural soils over the next 50-100 years has been estimated to be in the order of 20-30 Pg C; see Table 2 (Paustian et al 1988).

Because little is still known of how agriculture in different parts of the world will be affected by climate change, considerably more research remains necessary before any conclusions can be reached.

7. LAND REHABILITATION, FOOD PRODUCTION AND BIODIVERSITY.

This is a major topic that can only be covered very superficially in this document. Land rehabilitation is a serious problem in many parts of the world, and biodiversity is a contentious subject for which there is not even an agreed common methodology for assessing it. Land use causes various effects on biodiversity, the main being a reduction of biota in comparison with pristine forests. The extent to which biodiversity is affected depends on many and varying factors e.g. agricultural practices, type of crops, harvesting methods and forests type.

Agricultural development and the preservation of biodiversity is often perceived as an obstacle to modernisation. Often such conflict does not exist and, on the contrary, it can be very beneficial. As Thrupp (1998) puts it “evidence shows that integrating biodiversity and agriculture is beneficial for food production, ecosystem health, and for economically and ecologically sustainable growth”.

However, the conservation of biodiversity has a cost and thus it is difficult to convince farmers and decision-makers to spend money on any proposed measure if we are not capable of quantitatively expressing the values of biodiversity in such a way that they can be compared. But one of the problems is that the development of methods for quantification of biodiversity is a very complex topic in its own right, since the definition of biodiversity covers such a broad range of aspects. Even the choice of valuation method for biodiversity is a controversial subject e.g. biologists and social scientists, in particular, object to the use of monetary valuation, claiming that the preservation of biodiversity is a matter of principle, and should therefore not be converted into a tradeable unit. Ecological economists point out that certain changes in nature have irreversible consequences, such as the extinction of a species, which means that natural and hard capital are not freely substitutable. There is, however, general agreement on the fact that political priorities always have to be set, and all measures have a cost.(Pearce & Morgan, 1994).

A novel idea has been suggested by Hohmeyer (1997) and is based on the expert judgement of protection needs in combination with a public willingness-to-pay for protection of biodiversity. However, even expert judgement on areas required for biodiversity protection is based on many assumptions.

This is a topic beyond the scope of this paper, but suffice to say that generally-speaking and until now, the data indicates that biofuel production is less intensive than the production of traditional annual crops, and also provides some benefits for biodiversity compared to intensive agricultural practices. Negative effects on biodiversity in connection with forestry are caused mainly by bad logging operations. The harvesting of forest residues does not necessarily have a major effect on biodiversity. Annual energy crops, however, have impacts on biodiversity that are more or less the same as those of intensive agriculture.

It is now recognised that the heavy dependence of developing countries on developed country agricultural technology and management practices, while succeeding in increasing overall productivity, has significant undesirable effects. These negative effects include the discouragement of mixed cropping and minimal tillage practices, rapid increase in the use of chemical fertilisers and emphasis on engineering rather than biological approaches to soil stabilisation, etc. Without proper management practices, this can lead to serious effects on biodiversity and other environmental practices.

The developing countries' modernisation drive should not necessarily be at the expense of the environment, sustainability and biodiversity. They should try to find sound alternatives and combine modernisation with local solutions while learning from the mistakes of intensive agricultural practices in both the industrial and developing countries.

Awareness of the multifunctional character of agriculture and land, embodied in the so-called MFCAL Approach, can act as a useful approach for identifying the respective importance of each of the social, environmental and economic functions, and design the best balance among the functions, taking advantage of the synergies among them and realising the trade-offs. Bioenergy production, as a function of agriculture, can be optimised so as to reduce to the minimum the impact on the biodiversity function; it can also, in areas of high density of population, enhance the employment function.

7.1 Food versus fuel production.

This has always been a controversial topic because of the many misconceptions surrounding land availability, particularly at a time of rapid population growth. To better understand this issue it is necessary to understand the intertwined nature of food and energy production. There is plenty of land available but the issues are complex from political, socio-economic, cultural, and managerial points of view.

Land availability is perceived as a constraint to large scale production of biomass but only from a perspective of current agricultural practices which often comprises mismanagement, waste, unsustainable practices, etc. In tropical countries there are large areas of deforested and degraded lands that would benefit from the establishment of bioenergy plantations. For example, from a detailed analysis of 117 tropical countries it was found that 11 countries were suitable for expansion of the forest area up to 553 Mha. The World Resources Institute found that within 50 tropical countries, 67 Mha could be realistically converted to plantations over the next 60 years, more than 200 Mha could be regenerated and a further 63 Mha are available for agroforestry. Yet another study found that 265 Mha were available for reforestation and 85 Mha were available for agroforestry. FAO (1996a), after studying the potential cropland resources in over 90 developing countries concluded that as a whole, the developing countries will only be using 40% of their potential cropland in 2025, although there are wide regional variations.

Large areas of surplus agricultural land in USA and EU could become significant biomass producing areas. In the USA, farmers are paid not to farm about 10% of their land, and over 30 Mha of cropland were set aside to reduce production or conserve land; a further 43 Mha of croplands have high erosion rates and a further 43 Mha have “wetness” problems, which could be eased with a shift to various perennial energy crops. In the EU, up to 15% of arable farmland can be “set-aside” although the percentage has varied over the last 5 years (Hall, 1999).

Thirty five years ago about half the population (1 billion people) of developing countries were undernourished - today it is under 20% (about 800 million people). During this period cereal yields, total cereal production and total food production in developing countries more than doubled while the population grew by 75%. As a result average daily calorie supply increased by a quarter from under 2,000 calories per person per day in the early 1960s to almost 2,500 calories in the mid 1980s, of which 1500 calories was provided by cereals (Conway, 1997). This trend has continued into the mid 1990s so that the last 30 year period has seen a worldwide 19% per capita increase in food for direct human consumption with a 32% increase for developing countries as a whole. Today only 10% of the world population lives in countries with “very low” per capita food supplies (under 2200 calories) down from 56% in 1969-1971 (Hall, 1998).

However, these gains have been very unequal. Sub Saharan Africa countries appear no better and often worse off today than 20 years ago; India has increased its food grain production four fold from 50 to 200 Mt, while population has increased three fold from 330 to 960 million.

It is understandable that there should be great deal of concern when land is suggested to be converted to energy purposes while there are so many people undernourished around the world. Food production is a complex socio-economic, political, and cultural issue that goes beyond the earth’s carrying capacity to produce food. If farmers are given the opportunity through capital, economic incentives, land tenure rights, etc, they will be able to produce more food that has been the case so far.

8. POLICY APPROACHES TO AGRICULTURE AND ENERGY

Agriculture has been considered by many governments as a secondary activity for far too long; industrialisation was a higher priority despite the fact that agriculture has been the main source of income and employment in most developing countries. A number of important policy changes have been taken place in the past decade that mark an important shift, such as an enhanced role for market forces and a reduced government role.

Agenda 21 recommends that rural people should start a process of “environmentally sound energy transition away from unsustainable energy technologies”. It also calls on countries to develop policies and strategies to spur change away from “unsustainable consumption patterns”, including energy consumption patterns.

These changes are leading to a new paradigm with major implications for agriculture and energy. Up to the late 1980s, the cold war played a major role in determining our energy thinking. With the end of the cold war four main trends began to emerge:

i) privatisation, decentralisation, and liberalisation of the energy sector. The way in which energy is delivered to the final consumer (and also produced) is undergoing great change with energy production and delivery increasingly passing to the private sector which is gradually replacing state monopolies; there is also a greater reliance on the market as a means of allocating resources;

ii) greater awareness of the environmental impacts of energy production and use, and a willingness to address problems such as climate change and environmental sustainability. The concern with energy availability has been replaced by the concern as how to provide energy without endangering the environment and the stability of the global climate;

iii) prevalence of low oil prices which has hampered the development of alternative energy sources; and

iv) greater global co-operation to alleviate the most pressing needs and problems related to poverty, equity, and affordable energy.

It seems that many of the expectations and predictions set in the 1981 Nairobi Programme of Action (NPA), resulting from the United Nations Conference on the Development and Utilization of New and Renewable Sources of Energy, have failed to materialise for a range of different reasons: i) the predicted energy crisis forecast at the beginning of the 1980s did not occur. Instead, the energy consumption growth rate of the developing countries fell by about 50%, and also the alarming woodfuel deficit situation predicted for many developing countries did not materialise. Lack of data led to controversial interpretations of the energy situation in many countries, and thus often erroneous decisions were taken in the evaluation of resources resulting in many wrong policy decisions; ii) R, D&D activities in renewables, particularly in rural communities, were hampered by low prices of fossil fuels, subsidies, etc; iii) many schemes focussing on the creation of infrastructure, management of existing forests, dissemination of improved cooking stoves, etc, received a great deal of support but often failed (with notable exceptions) to meet expectations; iv) education and training activities have failed to create a critical mass of experts able to deal with bioenergy matters and this constrained the realisation of many bioenergy activities; v) environmental and health implications of biomass energy have not received sufficient attention in the past (better combustion devices and ventilation, change in cultural practices, the need to reduce emissions, higher investment required for advanced less polluting technology, etc.).

It is evident that the world is presently undergoing important changes which are leading to a new political and economic order and the globalisation of the economy. These changes are also affecting the way we produce and use energy. This decentralised model could bring increasing opportunities for many individuals involved in bioenergy. These developments provide valuable new insights to prepare new strategies and policies for the coming century for biomass energy. Certainly, there are now more institutions around the world than ever before to promote these changes. As an FAO (1996b p. 61) report puts it “the use of fuels derived from forests and other biomass has tremendous potential as an environmentally friendly, technically mature, economically feasible and socially acceptable energy practice. It could contribute significantly to a more rational and equitable “New Energy Order” that is less reliant of fossils fuels and the costly infrastructure associated with them”.

8.1 Sustainable agriculture and bioenergy

Energy is central to this new paradigm and a challenge to the aim of sustainability. The new scenario requires that social and environmental costs and benefits of energy production, delivery and use be included in decision making along with market and investment factors to put all energy sources on a more equal footing; subsidising polluting fossil fuels should be stopped. There remain many unanswered questions: how can energy be provided in a sustainable manner?, what kind of energy carriers are needed, and at what level of efficiency?

By the year 2030 as many as 8 billion people may be on the planet. This raises the inevitable question of whether they can all be adequately fed. The answer may be not if present practices do not change considerably. To feed a growing population satisfactorily more than increased agricultural production is required; political changes are needed that prioritise agricultural R&D, change people attitudes, improve the quality of life of many, and provide incentives and motivation. It is a major precondition to have abundant and accessible sources of energy if this is to be achieved.

Scientific and technical advances, no doubt, will play a major role but in the end it is possible that the most difficult obstacle may have more to do with economics, sociology and politics. In energy-environment interactions sustainability is critical. The energy consumption patterns and monitoring of their impacts in an integrated framework needs to be studied in detail so that policy makers can use them to frame energy and environmental policies. Much of this information is not yet available.

Thus, for a strategy to achieve sustainable agriculture and rural development (SARD), and to also achieve sustainable energy development, an improved understanding of energy consumption and its environmental implications is needed. “A mechanism which can become a driving force in the quest for solutions that incorporate environmental considerations in the path of economic development is required” (Reddy, 1997 & 1998).

These are challenges facing all countries. Some countries are already moving towards more sustainable agriculture and energy systems through a change in policies and shifting role of the various stakeholders. Others are having to move faster, taking urgent measures to face immediate challenges to survival. One very interesting and documented case is Cuba. Cuba has faced recent changes of its agricultural system, which are having major significant impacts in both food and energy production. The break up of the Soviet Bloc in 1989 plunged Cuba into the worst economic crisis of its history. Its agriculture was highly dependent on imported pesticides, fertilisers, and farming equipment, and without these inputs, domestic production, led to an estimated 30 percent reduction in calorie intake in the early 1990s. The energy crisis was also particularly severe since all fossil fuels were imported, forcing the country to fasten the introduction of important structural changes in which, the sugar industry in particular, was envisaged to play an increasing role in energy supply.

Cuba was faced with a dual challenge of doubling food production with half the previous inputs. A transformation was promoted from a conventional, large scale, high input, mono-crop agricultural system to a smaller scale, organic and semi-organic farming system. It focussed on utilising local low cost and environmentally safe inputs, and relocating production closer to consumers in order to cut down on transportation costs. Urban agriculture has been a key part of this effort. By 1994 urban residents joined a planned government strategy to create over 8,000 ha and 2,500 city farms in Havana alone. The success of these gardens has significantly contributed to the easing of Cuba’s food crisis, and in 1998 an estimated 541,000 tons of food were produced in Havana alone for local consumption. Some neighbourhoods are producing as much as 30% of their own subsistence needs. The opening of farmers markets and the legalisation of direct sales from farmers to consumers greatly increased production incentives for urbanites (Murphy, 1998).

In the mid 1990s Cuba saw an excellent opportunity to link the recovery of agriculture, particularly sugarcane, and the design of a new energy supply system based increasingly on biomass energy. For example, in 1959 about 380 GW of electricity were generated from sugarcane bagasse, and over 1,500 GW in 1990. In the mid 1990s this potential was estimated to be over 2,500 GW. A major limiting factor has been lack of capital investment needed for the modernisation of this industry. Other options such as solar and wind energies are being developed for both rural and urban use.

8. 2 Bioenergy and rural development

Biomass energy has played and continues to play a major role in rural development. Indeed, in many rural areas of developing countries bioenergy constitutes almost the sole source of energy. This role has gone, until recently, largely unrecognised in many parts of the world by politicians and energy planners alike.

What could be the implications of an enhanced role of bioenergy in the future, and more specifically in the agricultural sector, if current energy scenarios projections are correct? The world is facing a future in which no single energy source is going to have a monopoly of supply, and in which energy efficiency and renewable energies should play a major role. One of the problems of traditional bioenergy is its low efficiency which will have to be tackled head on from environmental, energy, sustainability and economic perspectives. The clear message is that bioenergy production and use must be modernised. The availability of modern biomass energy carriers could have major implications for modernising agriculture in many developing countries which could be reflected in a sustainable increase in food production and economic growth. Already the modernisation of bioenergy through cogeneration of electricity from sugarcane bagasse in Brazil and India, production of biogas in Denmark, and improved stoves in China, is producing very positive effects.

9. CONCLUSIONS AND POLICY RECOMMENDATIONS.

The present study has proved that the energy function of agriculture, and the potential synergy of the energy function with other functions such as food production, environmental sustainability and social development are becoming increasingly evident. Trade-offs, mainly related to potential loss of biodiversity and the possible competition for land have also been discussed. This complements the abundant evidence that shows that the multifunctional character of agriculture and land makes a significant contribution to food security, rural development and environmental sustainability, at local, national, regional and global levels.

The growing interest in bioenergy reflects a combination of environmental, ecological, and sustainability concerns: its potential energy contribution; its versatility and global availability; substantial local benefits; technological advances; and improved economic viability. For the first time bioenergy is being recognised as a significant component in many future energy scenarios, ranging from 59 to 145EJ in 2025 compared to current use of 55EJ. The rapid increase of bioenergy production and use could thus have major implications for agriculture in the future.

The precise implications for agriculture of such potential increase of bioenergy production and use are difficult to foresee. These implications will not be uniform but, in fact, quite different in many parts of the world, given the differing levels of social, economic, agricultural, and technological development, in addition to differences in culture, geography, resource endowment and climate, at regional, national, and local levels. It is expected that different policy responses will apply to specific circumstances.

A major problem with traditional forms of bioenergy is that they are often used inefficiently and little useful energy is produced. Far more energy can be economically produced than at present so that the biomass energy potential could be increased considerably. Indeed low energy efficiencies, particularly in rural areas of developing countries, have not been adequately addressed nor has it been a priority issue. This is a major challenge that must be met since it has serious energy and environmental implications. This contrasts with bioenergy which, if produced efficiently and on a sustainable manner, can have many environmental and social benefits compared to fossil fuels. These benefits range from socioeconomic development, waste control and disposal, and nutrient recycling to job creation, CO_2 mitigation, and improved land management, all depending on the nature and technology in question.

A major, and perhaps misconceived concern, is the long term environmental and ecological impact of large-scale monoculture energy plantations. Recent experience in Brazil, Scandinavia and other countries and ongoing research indicates that with careful management practices, land use planning, and appropriate selection of species and clones, most of the negative effects can be avoided and positive attributes can be emphasised.

Land availability and bioenergy production are intrinsically intertwined. Recent studies seem to demonstrate that the perceived constraints on land are not well founded, not-withstanding local priorities of land use. Competition of bioenergy with food production is another concern voiced, but evidence also seems to demonstrate that the main problem lies elsewhere in food production and consumption patterns and implies lack of purchasing power, inequality, land tenure problems, grains used for livestock, underutilisation of agricultural land, lack of appropriate credit, investments and infrastructure, export of crops, wars, and political interference.

Farmers, given the opportunity, have demonstrated their capacity for change and innovation if they see clear economic advantages. With proper support (extension services, infrastructure, financial, etc) farmers are able to produce far more food and energy. It is important to remember that food and energy are mutually interrelated and complementary. Bioenergy programmes which couple with integrated farming can improve food production by making energy and income available where it is most needed, and in a more environmentally and sustainable manner. Traditional bioenergy is labour intensive and employs large numbers of people, often unrecorded, and can constitute an important source of income for many farmers. High labour intensity, however, may have some negative implications for economic development.

A range of technological advances are opening up new opportunities. Growing environmental and ecological pressures, combined with technological advances, and increases in efficiency and productivity, are making biomass feedstocks economically more attractive in many parts of the world. The most immediate commercial prospects are in cogeneration (heat & electricity) spearheaded by the pulp/paper and timber industries using wood wastes, bagasse from the sugarcane industry, and other agricultural residues such as rice husks, for use in agroindustry.

For the energy function of agriculture to play its full role, particularly in its modern forms, incentives might be necessary at least to put bioenergy on more equal terms with entrenched (subsidised in terms of the non-internalisation of the environment costs) fossil fuels. The experience from countries such as Austria, Sweden and the USA that have a significant modern bioenergy contribution, clearly indicates that this is a necessary condition. In the longer term, however, market forces must be allowed to play their role.

Predicting energy trends is notoriously difficult. Future energy supplies could be more decentralised and with renewable energies playing an increasing role. Increased energy efficiency together with technological developments is likely to curtail the rate of increase in energy demand. Fossil fuels will continue to dominate well into the next century, while bioenergy in its various forms will also increase their market share.

Major R&D and policy gaps need to be addressed especially as they relate to sustainable production and use of bioenergy in an environmentally acceptable manner. A major problem with bioenergy is that until recently it has had a low priority in the allocation of resources for R&D, planning and implementation. Thus it will take time to reverse this previous neglect.

Bioenergy should not, nevertheless, be regarded as a panacea for solving agricultural and energy problems in the rural areas, but as something which can play a significant role in improving agricultural productivity while contributing to energy supply and environment sustainability. Its final contribution will depend on a combination of political, social, cultural, economic, and environmental considerations.

9.1 Policy Recommendations

Policies and institutions

- bring the **vast potential of bioenergy for CO_2-mitigation, energy efficiency and rural development** onto the political agenda – particularly of national and international agricultural authorities;
- stress the large potential **role of bioenergy technologies in the transition process to a more clean and sustainable energy scenario** using carbon substitution (substituting biofuels for fossil fuels) and the opportunities this represents for the agricultural sector;
- stimulate the **integration of the energy aspect into the agricultural sector** and the potential of bioenergy for the energy sector. International organisations like World Bank, FAO and other UN-agencies should take the lead in this by allocating resources and manpower into the field of bioenergy and agriculture. Their example would help support similar actions by national governments, NGOs, etc;
- support those countries with relatively little capacity in the bioenergy field in assessing their bioenergy and agriculture potential and in negotiating investments. They might also be in need of **support to acquire technologies, skills and investments** (e.g. under CDM) to fully develop their potential in line with the needs of their country. International organisations are in the perfect position to act as "honest brokers" and support them in this capacity-building process, for instance through the provision of information and technical assistance;
- use the **existing trends of privatisation and decentralisation in the energy sector** for stimulating research and investment in the production and use of bioenergy and agriculture;
- promote and formulate **clear policies to promote bioenergy** on an equal footing with conventional sources by internalising the external costs of conventional energy, that is, ensuring that the polluter pays the full costs.

Research, development and extension

- assess in greater detail the **interrelationships between energy and agriculture** for different agricultural systems, plants and management systems – especially the relation to climate change;
- study and promote the **integrated management of energy and other inputs** such as water and fertilisers to gain a better understanding of the synergies regarding natural resource management and to develop sound management practices and tools;
- develop **tools for the rapid field assessment of bioenergy potential** in agricultural production areas and transfer these tools to agricultural authorities and farmers;
- promote **R&D of promising technologies** for the production and use of biomass energy and conversion technologies and efficient energy flows

Projects and financing

- stimulate the implementation of **presently commercially viable bioenergy** technologies, like cogeneration with agroresidues, sustainable charcoalmaking, etc. through making available capital, credit and tax incentives. Use these projects to demonstrate to the world at large the potential and viability of bioenergy and agriculture.
- tap on **existing mechanisms** such as the Clean Development Mechanism and the Global Environment Facility to finance demonstration and research projects; also to attract international finance for sustainable agroforestry projects in remote and underdeveloped areas that have the potential of producing energy and water for more developed areas;

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Table 1. The role of modernized biomass in future global energy use. *Present biomass energy use is about 55 EJ/year*

Scenario	**Year of Scenario**		
	2025	**2050**	**2100**
IEA (1998)	60*	-	-
IIASA/WEC (1998)	82** 59***	153** 97***	316** 245***
Shell (1996)	85	200-220	-
IPCC (1996)	72	280	320
Greenpeace (1993)	114	181	-
Johansson *et al* (1993)	145	206	-
WEC (1993)	59	94-157	132-215
Dessus *et al* (1992)	135	-	-
Lashof and Tirpak (1991)	130	215	-

* 2020 (Total primary energy supply)
** Scenario A3 (High Growth – biomass and nuclear)
*** Scenario C1 (Ecologically driven – large renewables, no nuclear)

Source: Hall (1999).

Table 2. Summary of the global potential mitigation of C02 by agriculture (modified from Cole et al., 1996).

Mitigation category	**Annual (PgC)**	**Cumulative[a] (PgC)**
Soil C sequestration		
- Better management of existing agricultural soil[b]	**0.4~0.6**	**22-29**
- In permanent set-aside agricultural land in temperate regions		
(a) upland soil[c]	**0.003-0.03**	**0.15-1.5**
(b) wetland restoration[d]	**0.006-0.012**	**0.3-0.6**
-Restoration of soil C on degraded lands[e]	**0.24~0.24**	**1.2-12**
Reduced fossil C emissions		
- Reduction in energy use by agriculture in industrialized countries[f]	**0.01-0.05**	**0.5-2.5**
Fossil C offsets[g]		
- Dedicated biofuel crops, shelterbelts and agroforestry	**0.3-1.3**	**15-65**
- Crop residue use for biofuel	**0.2-0.3**	**10-20**
Total potential $C0_2$ mitigation	**0.94-2.53**	**49-131**

a - Cumulative amounts are for a 50 year period.

b - Assuming a recovery of one-half to two-thirds, of the estimated historic loss (43 Pg) ofC from currently cultivated soils (excluding wetland soils) over 50 years.

c- Based on a potential C sequestration of 1.5-3 Pg, from a 15% set-aside of surplus agricultural lands (of a total of 640 Mba) in industrialized countries. Annual and cumulative rates consider a 10-50% implementation.

d- Assuming restoration of 10-20% of former wetland area (8 Mha) now under cultivation in temperate regions.

e- Assuming potential soil C increases of 1-2 kg m^2 over a 50 year period, on 10-50% of the moderately to highly degraded land (1200 Mha globally. Oldeman et al. 1990).

f- Based on current use by agriculture of 3.5% of total fossil emissions by industrialized countries (2.8 Pg C; OECD 1991) and assuming reductions of 10-50%.

g- Values from Table 3.

Source: See Paustian et al (1998).

Table 3. Potential C02 mitigation through fossil C offsets by agricultural biofuel production (modified from Cole et al., 1996 and Sampson et al., 1993)

Biofuel option	Land area (Mha)	Net C yield (Mg C ha' y')	Net C amount (Tg y')	Energy substitution	C * reduction
Dedicated Energy crops					
Temperate	26-73	5-9	130-660	.65-0.75	80-490
Tropical	41-57	6-12	250-680	.65-0.75	160-510
Temperate shelterbelts	13-26	2-4	30-100	0.5-0.7	10-50
Tropical agroforestry	41-65	3-6	120-390	0.5-0.7	50-200
Crop residues			350-460	0.6-0.7	210-320
Total			**880-2290**		**510-1570**

* C emissions reduction (Tg/year)

Source: Paustian et al (1998).

Table 4. Summary of global energy content of potentially harvestable (1) residues (10^6GJ)

Region	Crop	Forest	Dung	Total
Developing countries	21,510	16,671	13,328	51,509
Industrial countries*	16,528	18,802	6,295	41,626
World	38,038	35,473	19,623	93,135

- (1) Note on harvestable residues:
- Crops. Includes only the world's main crops e.g. wheat, rice, maize, barley and sugarcane, and a residue recovery of 25%.
- Forests. These are the same in all countries; it assumes a 40% from the total cut for both industrial roundwood and fuelwood + charcoal.
- Dung. Recoverable dung is assumed to be 25% of the potentially hartvestable e.g. 1/8th of total production, dry weight. (For further details see source).

* Includes countries from the former USSR

Source: Wood & Hall (1994).

Table 5. Summary of policy instruments and measures that influence GHG emissions from agriculture

Economic instruments	**Regulatory legislation**	**Information, education**	**Research and Development**
*reduction/reform of agricultural subsidies	*regulations on fertilizer application	*information on ways to improve agricultural productivity	*R&D on ways to reduce enteric fermentation, reduce liquid manure production, more efficient ways to apply fertilizers
*cross compliance schemes	*standards on N levels in the soil	*codes of good agricultural practices	*R&D on the uptake and loss of carbon in forests
*taxes on fertilizer use	*limits on burning of straw in open fields		*R&D on the production and recovery of energy from waste
*subsidies for converting to organic agriculture	*restrictions on livestock density		
*set-aside payments for forestry	*requirements for farmers to adopt mineral accounting systems		

Source: Hedger et al (1996).

Conversion Table.

EJ = 10^{18}J
GJ = 10^{9}J
Gt = 10^{9}t
GW = 10^{9}W
Pg = 10^{15}g
Tg = 10^{12}g

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