Fossil, human or bio-energy?

Agriculture can be defined as the human activity which arranges the conversion processes of energy, nutrients and water by plants and animals in such a manner that useful products such as food, feed, fuel, fibres and fertiliser become available. Beside human and solar energy, which are the basic energy sources for this activity, other sources of energy are also used such as fossil energy and bio-energy (energy from biomass and activities of plants and animals, oxen as well as earthworms, bacteria and pest predators). Fossil energy is a finite resource, its use has considerable negative impact on the environment and most farmers in developing countries cannot afford fossil-energy-based technology. On short term however, without the use of fossil energy, it will not be possible to feed the many people who live in urban centres. This poses the question of which energy sources, and therefore, which technology should be used where and when. This article deals with some aspects of that question.

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Hunters, gatherers and shifting cultivators only need very limited labour inputs and simple tools. Natural processes such as regeneration and succession, and tools such as fire are used successfully and a high diversity of plant and animal species find domestic use. Where population pressure increases, more permanent agricultural systems develop. In these systems, more energy is needed to make and keep the land productive and provide protection against pests, diseases, weeds, droughts or floods. Technologies and tools are mainly based on the use of local resources. Production levels differ from very low in extensive systems in unfavourable conditions to relatively high in intensively managed systems in favourable conditions. if land is too steep, wet, dry or cold to be used for crop production, too much energy would be needed to make and keep this land productive in another way than by extensive livestock production or forestry. Where animals are used as draught power, it is possible for farmers to cultivate more land or to make time free for other activities.

Modern systems

In modern agricultural systems, human and animal labour, to a high extent, are replaced by external inputs such as synthetic fertilisers, pesticides and mechanization. For the production and operation of these inputs, relatively high amounts of fossil energy are needed. An advantages of these systems is that production can be concentrated on a limited number of crops which are most profitable and productive. The reduced demand for human labour frees farmers from drudgery and makes labour free for activities outside agriculture. The availability of cheap fossil energy makes it possible for people to leave the farm system in great numbers and find livelihoods in urban centres as consumers and producers of industrial products and services.

Energy balance

Crop yields and food supplies to consumers are directly linked to energy use. Sufficient energy is needed in the right form and at the right time. Energy flows in agriculture can be analysed and made visible in an energy balance which can be used as information base for decision making concerning energy use and policies. By assigning an energy value to inputs, outputs and through-puts (internal inputs and outputs), a common basis is established for comparing the effectiveness and efficiency of the whole system or subsystems. However, it must be kept in mind that different energy forms have different values to mankind. A calorie of edible food or human labour is fundamentally different from a calorie of oil or fertiliser as they have different uses, costs and environmental and social effects. Energy balances are made to compare cropping systems as well as whole farm systems from an use-of-energy viewpoint. To really compare farm systems, e.g. low-external-input versus high-external-input systems, the energy needs for the flow of food and waste through the consumption subsystem and the energy needs for production and delivery of external inputs should be included too. Defining system boundaries is important in this respect.

Energy output/input ratio

In these energy studies it has been found that agriculture which only relies on human labour has a higher energy output/input ratio than agriculture in which animal labour is used. Modern agriculture has again lower energy output/input ratios. In western countries, in intensive market-oriented agriculture, the energy output/input ratio even tends to come close to one. To produce one unit of food energy, nearly as much fossil energy is needed in these systems. The first two categories of systems are clearly more efficient with energy than modern systems. This, however, does not yet mean, as is often thought, that these systems should be preferred, as productivity is an other important criterion for judgement. Experiences show that there is a direct relation between the level of energy use, either human, animal or fossil, and the level of production per unit of land. In fossil-energy-driven systems, the relatively high energy use explains the relatively high productivity. However, there are organic, integrated systems (see e.g. box on V AC) in which virtually no fossil energy is used, which, in terms of overall production, are at least as productive as modern systems, but have less negative impact on the environment and may be socially more acceptable. That the source of energy is not important for the level of production is also demonstrated by comparative research in the Philippines (Kuether and Duff 1981), where it was found that the same yield of rice could be obtained in mechanical, transitional and traditional farms . Basing policies on comparing energy balances only, therefore, can lead to wrong decisions if these data are not combined with information on e.g. production, availability, cost, impact on environment, gender and the community as a whole.

Conservation of fossil energy

The rapid increase of population and the push for development make it necessary to use more energy for agricultural production and to use this energy more efficiently. However, further dependency on fossil energy increases the risk that rural development will be seriously affected by rising prices or stagnating imports of oil as happened during the Gulf war. Furthermore, fossil energy is a finite resource which has considerable negative impact on the environment. This makes it clear that future development cannot rely heavily on non-renewable fossil energy supplies. For development, it will be crucial to conserve fossil energy and to develop renewable energy resources. Numerous opportunities exist to save fossil energy in agricultural production. Some of these opportunities are:

- reduced or zero tillage
- agroforestry
- efficient use of irrigation water
- efficient and balanced application of mineral fertilisers
- integrated plant nutrient systems
- recycling and improved management of organic waste
- biological nitrogen fixation and phosphate mobilization
- biogas
- integrated pest control
- integrated energy systems
- improved agricultural tools and mechanization
- improved management skills of farmers.

Apart from reduction of energy use there are also opportunities for replacing fossil energy by renewable wind and solar energy, for example for water pumps.

Low-external-input agriculture

Prices of fossil-energy-based inputs, if at all available, are relatively high in regions where population density is low or transport is difficult. In more marginal regions and for more marginal farmers and certainly for low-price and subsistence crops these commercial external inputs cannot be used economically. These farmers are by force low-external-input farmers. Probably, this concerns about 70-80 percent of the land used for agricultural production and about 70-80 percent of the farmers. Farmers who are high-external-input farmers today can be low-external-input farmers tomorrow, as governmental policies and prices of

agricultural inputs and agricultural products have a strong influence on the technology and strategies farmers can use. For example, the recent drop of subsidies on synthetic fertilisers in several countries in Africa and Asia forced farmers to use synthetic fertilisers more efficiently or, even, to fall back on farm-internal resources such as manure, mulches, and biofertilisers.

Bio-energy

For many low-external-input farmers their first priority is to find ways of increasing production and securing ecological sustainability without increasing the demand for human labour. For them the question is how to use locally available energy sources, human energy as well as bio-energy more efficiently. This can be achieved by making skilful use of specific sources of bio-energy. Animal power is a well known example but also organisms such as soil organisms which fixate nitrogen, sollubilize phosphate, decompose organic matter, improve soil structure and predate pest organisms can be used effectively. Making better use of processes such as natural regeneration, succession and complementarity, and positive or negative interactions between organisms, e.g. in intercropping or crop-livestock systems can lead to higher productivity of human labour and increased production too.

Integrated energy systems

Use of a mixture of energy technologies in crop and/or livestock production is referred to as an integrated energy system. The primary outputs or by-products from one component or element become the input for another element so that the overall energy system output is optimised. In box 1 an integrated agricultural system from Vietnam is described. These systems function best in more humid regions with a high level of human organisation where recycling of organic waste is economically possible due to relatively good prices for agricultural products and short distances between producers and consumers. In countries with a high population density such as in South East Asia and China farmers have long-time experience with these systems. Energy efficiency, labour productivity and total production of these systems can be very impressive. In China, integrated energy systems are being developed further into modern, capital intensive, high productive systems (NRC 1981). For the introduction of these systems there are two major limitations. The first is the investment in capital and labour required. For farmers, even in systems as described in box 1, this can be a considerable constraint. The second limitation is the complexity of integrated systems, which requires a relatively high level of management skill for efficient operation.

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Box 1: The VAC integrated system

The VAC integrated system VAC is an acronym of 3 Vietnamese words: Vuon (garden, orchard), AO (fish pond) and Choung (stall, pigsty). VAC is an ecosystem in which gardening (V), fish rearing (A) and animal husbandry (G) are closely integrated with one another, enhancing economic effectiveness and contributing to protect/improve the environment. The VAC technology is a highly intensive farming technology making optimal use of available solar energy, land and water and achieving a high economic efficiency with low capital investment.

A traditional system

The VAC practice is a long-standing tradition of the Vietnamese people stemming from their experience with farming in the lowland areas of the Red River Delta. Before building their houses, Vietnamese farmers have to prepare a raised patch of ground by digging a pit which later forms a fish pond in front of the house. Various species of crops are grown in the garden under different farming technologies such as intercropping, mixed cropping, overlapping cultivation and multi-tier cultivation to make use of all available resources. The fruit trees are intercropped with vegetables, legumes and crops tolerant to shade. In the corner of the garden a few medicinal and spice plants are grown. All around the garden timber trees and rattans are planted as green fences. Various kinds of fish are reared in the pond so that feed resources at all levels are used (e.g. tench at top, roach at intermediate and tilapia at bottom level). Aquatic taros are planted around

the fish pond and marsh lentils are grown over part of the water surface as pig feed. Some gourd trellises are constructed above the water. Near the fish pond there are pigsties and poultry coops.

Recycling
There is an interactional relationship in VAC. Some of the produce from the garden is used to feed the fish, while the fish pond provides water and slime to irrigate and fertilise the garden. Some of the fish can be used as nutritious animal feed. Animal manure is applied in the garden and the litter/sewage from the animal pens is used for feeding the fish. People are an integral part of the VAC system, consuming the products and adding elements like fertiliser and animal feed to the system.

Regional modifications
The VAC technology has been promoted throughout the country. There are different VAC models suited to the conditions of the various regions:

- *Coastal and littoral:* A belt of maritime pine is planted on the outside edge of the garden to protect it from wind and sand. Timber trees and rattans are densely planted on a causeway that is banked up all around the garden as a protective fence. In the garden, coconut, fruit trees, mulberry and tuber crops such as sweet potato or arrow-root can be planted. Fish or shrimp are raised in brackish ponds and canals. An animal husbandry component involving cattle, buffalo, pigs and poultry (especially ducks) can be developed.
- *Mekong Delta area:* Because of the dry season and the saline aluminous soil, people make a habit of digging connecting canals to form the garden. Coconut or citrus trees can be grown depending on whether the water is fresh or brackish and in accordance with soil conditions. Coconut plantations can be intercropped with other plants of different canopy stages and proportions such as banana, orange, tangerine, lemon, grapefruit, plum and rambutan. A recent model is a coconut plantation intercropped with coffee and cacao, or with orange, pepper and coffee. Fish or shrimp are reared in the canals. Chicken coops are constructed above the canal with a pigsty close by. Bee-keeping is practised under the shade of the trees.
- *Midlands and mountainous areas:* Sloping lands are planted with hilly and forest gardens. Timber trees are planted above, with fruit trees/cash crops below, following the contour lines with furrow drains and edges for keeping water and preventing erosion. Groundnut, pulse legumes, medicinal plants and cover crops are grown beneath the trees. Pineapple is also used to control erosion. In front of the house is a market garden. Beside the well or fish pond is an animal shed with a hole for composting manure. At the foot of the hill there is a fish pond or fish are reared in a cage in the stream.

Advantages and constraints
VAC provides a varied and abundant source of foodstuffs, thus improving the family diet. With a greater availability of other food, rice consumption can be reduced, contributing to the achievement of food self-sufficiency and reducing malnutrition among children. Family income is increased. In some communes, in the Red River Delta, the income from VAC practice is 3-5 times (in exceptional cases 810 times) higher than that of the unit area under two rice crops. VAC improves and protects the environment and provides employment for people of different ages and capabilities. However, although the VAC practice is an age-old tradition and is promoted nation-wide, the number of VAC families still practising it, is still limited. Most of the gardens use diseased and low-yielding varieties/seedlings resulting in low economic efficiency and bad quality products. Achievements remain low because our country has suffered severely from the war and many regions have experienced continuous natural calamities for years. The farmer's life remains difficult.

Association of Vietnamese Gardeners
During the period of 1985-86, the Vietnamese Government set forth the policy of encouraging the development of family economy. In 1986 the Association of Vietnamese Gardeners was founded. This is an NGO which promotes VAC development, provides guidance, support and transfer of technology related to VAC practice, and exchanges experience and collaborates with concerned international organisations so as to develop VAC activities in Vietnam. At present the association (VACVINA) has branches in 26 provinces.

We hope to widen our relationship with international and non-governmental organisations and foreign associations of gardeners especially of ASEAN countries in order to exchange experiences and enjoy mutual cooperation which will support our activities.

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