ECO – EFFICIENT APPROACHES FOR INTEGRATION OF CROP AND ANIMAL PRODUCTION SYSTEMS

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Abstract: The concept of eco-efficiency has often been considered a key element in the development of sustainable farming systems. Eco-efficiency is related to both 'ecology' and 'economy' and is concerned with the efficient and sustainable use of resources in farm production and land management. Eco-efficiency will be increased when a given level of production is achieved using less resources, with less losses to the environment and without sacrifice to the productive potential of the land or economic performance. The efficient use of plant nutrients, pesticides and energy and the minimization of greenhouse gas emissions are all key concerns that affect eco-efficiency.

Introduction: Agriculture is the human enterprise that is most susceptible to climate change. Subsistence agriculture in the tropics is particularly vulnerable, as smallholder farmers do not have adequate resources to adapt to climate change. However, there are significant opportunities for agricultural mitigation of climate change. Many agricultural practices such as agroforestry systems and integrated crop-livestock systems may play a significant role in reducing the emission and mitigating the atmospheric accumulation of greenhouse gases (GHG). These systems could help smallholder farmers adapt to climate change while contributing to restoration of degraded lands.

Eco-efficient agricultural production uses resources more efficiently to produce more food, enables family farms to be more competitive, and delivers sustainable increases in productivity, while avoiding natural resource degradation and negative externalities. Integration of crops and livestock was a common approach to agricultural production throughout the world. Greater integration of crop and livestock systems may impart major benefits to the environment and to development of sustainable agricultural production systems. The agricultural revolution over the next 40 yr has to be the eco-efficiency revolution, with which scarce resources of land, water, nutrients, and energy are used.

Integration of crop animal farming systems: Population growth, urbanization and income growth in developing countries are fuelling a substantial global increase in the demand for food of animal origin, while also aggravating the competition between crops and livestock (increasing cropping areas and reducing rangelands). The livestock revolution is stretching the capacity of existing production, but it is also exacerbating environmental problems. Therefore, while it is necessary to satisfy consumer demand, improve nutrition and direct income growth opportunities to those who need them most, it is also necessary to alleviate environmental stress. Conventional agriculture is known to cause soil and pasture degradation because it involves intensive tillage, in particular if practiced in areas of marginal productivity. Technologies and management schemes that can enhance productivity need to bedeveloped. At the same time, ways need to be found to preserve the natural resource base. Within this framework, an integrated crop-livestock farming system represents a key solution for enhancing livestock production and safeguarding theenvironment through prudent and efficient resource use. The increasing pressure on land and the growing demand for livestock products makes it more and more important to ensure the effective use of feed resources, including crop residues.

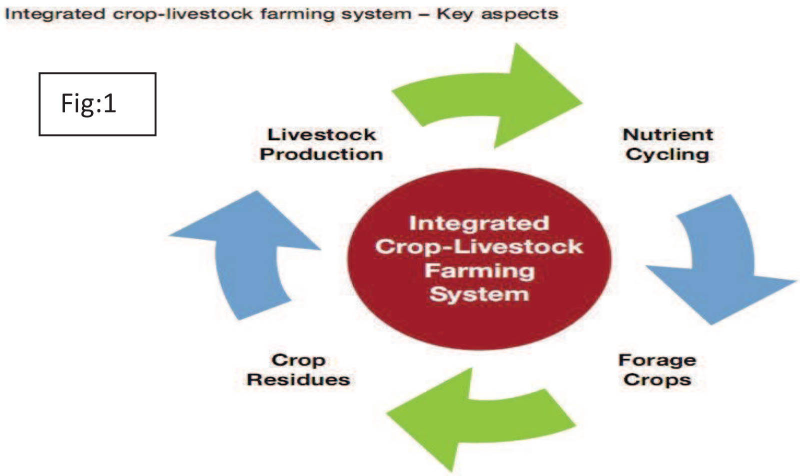
An integrated farming system consists of a range of resource-saving practices that aim to achieve acceptable profits and high and sustained production levels, while minimizing the negative effects of intensive farming and preserving the environment. Based on theprinciple of enhancing natural biological processes above and below the ground, the integrated system represents a winningcombination that

(a) reduces erosion

(b) increases crop yields, soil biological activity and nutrient recycling

(c) intensifies land use, improving profits

(d) can therefore help reduce poverty and malnutrition and strengthen environmental sustainability.



In an integrated system, livestock and cropsare produced within a coordinated framework.The waste products of one component serve as a resource for the other.The result of this cyclical combination is the mixed farming system, which exists in many forms and represents the largest category of livestock systems in the world in terms of animal numbers, productivity and the number of people it services.Animals play key and multiple roles in the functioning of the farm, and not only because they provide livestock products(meat, milk, eggs, wool, hides) or can be converted into prompt cash in times of need. Animals transform plant energy into useful work: animal power is used for ploughing, transport and in activities such as milling, logging, road construction, marketing, and water lifting for irrigation. Animals also provide manure and other types of animal waste. Excreta has twocrucial roles in the overall sustainability of the system:

(a) ***Improving nutrient cycling:***Excreta contains several nutrients (including nitrogen, phosphorus and potassiumand organic matter, which are important for maintaining soil structure andfertility. Through its use, production is increased while the risk of soil degradation is reduced.

(b) ***Providing energy:***Excreta is the basis for the production of biogas and energy for household use (e.g. cooking, lighting) or for rural industries (e.g. powering mills and water pumps). Fuel in the form of biogas or dung cakes can replace charcoal and wood.

Crop residues represent the other pillar on which the equilibrium of this system rests. They are fibrous by-products that result from the cultivation of cereals, pulses, oil plants,roots and tubers. They are a valuable, low-cost feed resource for animal production, and are consequently the major source of nutrients for livestock in developing countries. The integrated crop livestock system has many advantages which include

• It helps improve and conserve the productive capacities of soils, with physical, chemical and biological soil recuperation. Animals play an important role in harvesting and relocating nutrients, significantly improving soil fertility and crop yields.

• It is quick, efficient and economically viable grain crops can be produced in four to six months, and pasture formation after cropping is rapid and inexpensive.

• It helps increase profits by reducing production costs. Poor farmers can use fertilizer from livestock operations, especially when rising petroleum prices make chemical fertilizers unaffordable.

• It results in greater soil water storage capacity, mainly because of biological aeration and the increase in the level of organic matter.

• It provides diversified income sources, guaranteeing a buffer against trade, price and climate fluctuations.

The overall benefits of crop-livestock integration can be summarized as follows:

• Agronomic, through the retrieval and maintenance of the soil productive capacity;

• Economic, through product diversification and higher yields and quality at less cost;

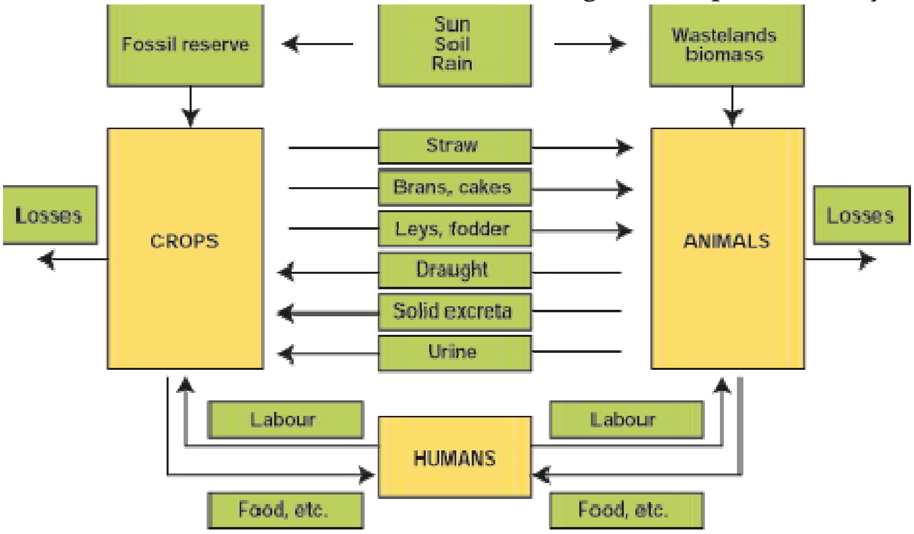
• Ecological, through the reduction of crop pests (less pesticide use and better soil erosion control); and

• Social, through the reduction of ruralurban migration and the creation of newjob opportunities in rural areas.

In integrated systems the exchange of resources such as dung, draught and crop residues takes place in different degrees based on the availability of land, labour and capital respectively

(Fig 2)

Fig 2:An outline of different resource flows in integrated crop-livestock systems



Most positive contributions of livestock to the environment are related to their role in integrated sustainable farming systems. In Asia, through centuries of experience, the integration of livestock, fish and crops has proved to be a sustainable system. In China, for example, the integration of fishpond production with duck, goose, chicken, sheep, cattle or pig raising increased fish production by two to 3.9 times. Also recognized were the ecological and economic benefits of fish utilizing animal wastes, a manageable system for small-scale farming. Environmentally sound integration is ensured in these systems: livestock droppings and feed wastes can be poured directly into the pond, where they constitute feed for fish and zooplankton; livestock manure can also be used to fertilize grass, which also constitutes feed for fish; vegetables can be irrigated from the fish ponds, and their residues and by-products can be used for feeding livestock.

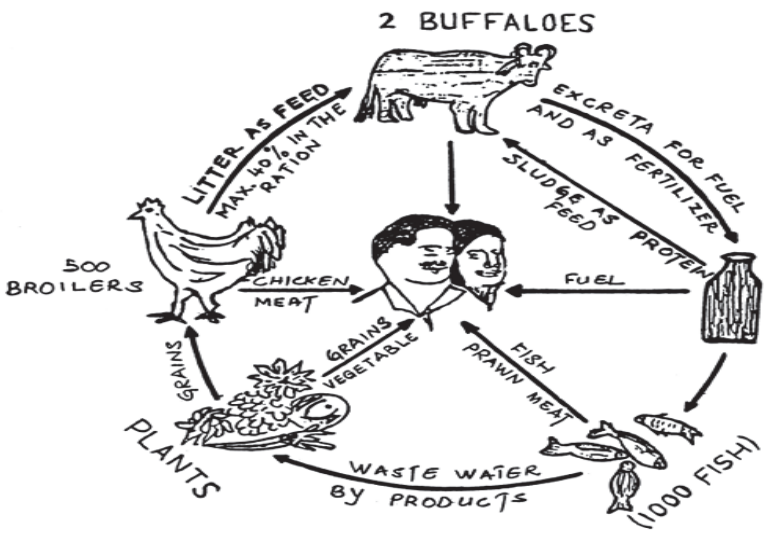


Fig 3: Integrated recycling model farm concept

The introduction of sheep grazing on legume forage/fuelwood fallows within traditional farming systems (cassava shifting cultivation) has been shown to greatly benefit the environment. In this way, degraded lands can be rehabilitated for crop production and further use of less fertile lands can be reduced. Maximizing both integration and recycling ensures the sustainability of animal production/agricultural systems. Such a system is now operational at the small-farmer level in Colombia and supports high levels of production (more than 3 000 kg of meat per hectare per year). It includes pig, sheep, duck and earthworm raising (in partial or total confinement), food crops, environmentally protective perennial crops such as sugar cane, nitrogen-fixing trees (*Gliricidia septum* and *Erythrina fusca*) or other multipurpose trees and water plants (*Azolla filiculoides*). Feed (sugar-cane juice for pigs and ducks, bagasse and tops for ruminants, fodder from trees and aquatic plants), energy (biogas and tree branches) and fertilizers effluent from biodigester and humus made by earthworms) are all produced on the farm.

Approaches to increase eco-efficiency: Increased ability to predict the availability of nutrients from soil and manures and better knowledge of threshold levels for weeds, pests and diseases provide the basis for precision farming with substantial reductions in external inputs and reduced environmental losses.

Reduction in rumen methanogenesis A major challenge in eco-efficient crop animal production is that the greater output and efficiency has to be achieved without further GHG emissions while maintaining or restoring agroecosystems. Considerable evidence of climate change associated with emissions of greenhouse gases (GHG). mainly carbon dioxid (CO_2), methane (CH_4) and nitrous oxide (N_2O) in the atmosphere has resulted in international efforts to reduce GHG emissions. The annual global methane production from livestock is about 80 Tg from enteric fermentation and India's contribution is about 11 Tg per year, which corresponds to 14 per cent of globaval influx of methane. Methane production by Indian cattle, buffalo, sheep and goat was 76.7, 97.0, 11.6 and 10.1 g/head/d, respectively.The nature and rate of fermentation of carbohydrates influence the proportion of individual VFA formed and thereby the amount of CH_4 produced in the rumen. Methane emissions from ruminant animals are reduced when they are fed some forage species to the mother production from enternc fermentation of Livestock.

Land use to maintain soil fertility: Soil organic matter content decreases with continued cultivation and cropping with arable crops, but increases under grass. It was found that changing land use from more or less continuous cereals to pasture increased soil organic carbon from 1.2 to 1.8% in 10 years, with soil N increasing from 0.13 to 0.17%. The annual increments in soil C and N were 1000 and 75 kg ha^{-1}, respectively. With grass, not only does organic matter content increase, but there is also an improvement in structure, as indicated by an increase in the proportion of water-stable aggregates.

The replacement of native perennial vegetation with annual crops (wheat and subterranean clover) results in a dramatic increase in deep drainage and aquifer recharge. Consequently, highly saline water may lead to salt accumulation in the rooting zone and reduce crop growth or cause crop failure. The inclusion of deep-rooted perennial species, such as lucerne, in a rotation will extract water to depth, reduce aquifer recharge and prevent increase in salinization. A similar approach using deep-rooted species is relevant to sustaining productivity of large areas of the world.

Improving carbon sequestration in soil: By using the concept of building an arable layer through improved carbon sequestration and combining this soil management technology with acid soil adapted cultivars of both forages and crops in integrated crop-livestock systems (agropastoral systems), farmers have the tools and technologies to transform the low fertility acid soils to increase agricultural productivity and mitigate climate change. In addition, an effective natural inhibitor of nitrification was discovered in the root-exudates of the tropical forage grass *Brachiaria humidicola*. Acid soil-adapted improved forage grass options with ability to regulate nitrification in soil and to reduce emission of N2O to the atmosphere can make significant contribution to improve nitrogen use efficiency of crop-livestock systems. The integration of these carbon and nitrogen technologies can improve the economic and ecological sustainability of crop-livestock systems in low fertility acid soil regions.

Conclusion: It can be concluded that eco-efficient farming should satisfy the following five key attributes:

(i) it uses resources efficiently and makes the maximum use of renewable inputs,

(ii) it is neither locally polluting nor does it transfer pollution to elsewhere,

(iii) it provides a predictable output,

(iv) it conserves functional biodiversity in relation to strengthening ecological processes, reducing greenhouse gas emission and pollution generally and limiting soil erosion,
(v) it is capable of responding rapidly to changes in the social, economic and physical environment. It is also crucial that eco-efficient farming satisfies economic criteria in relation to farm profitability.

Suggestions for eco-efficient approaches in crop animal production system:

- Reduced methane emissions from ruminant animals through the use of improved forages
- Improved carbon sequestration in soil
- Increase the organic matter in soil through cultivation of grasses
- Cultivation of deep rooted perennial grass species extracts water to depth and prevents increase in soil salinization
- Practice of new conservation system of crop management through simplified tillage practices and low use of inputs Adoption of organic farming practices.

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