An Introduction to AGRICULTURAL SYSTEMS

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Preface

The agricultural systems of the world represent a very large subject. Their study involves a great deal of fairly detailed knowledge, as well as a grasp of the structures and functions of the systems themselves. This book has been written as an introduction to such a study and it concentrates on an overall view, rather than on the detail, partly because of the need to relate the latter to some larger picture in order to appreciate the relevance and significance of the detail.

This problem—of seeing the relevance of component studies and the significance of physical, biological and economic detail, and indeed principles—is encountered by many agricultural students right at the beginning of their university careers.

A systems approach to the teaching of agriculture aims to help by providing a framework that can be clothed with detail as time and interest allow. The initial framework has to be simple and usable but it is also important to think clearly about the reasons for studying the subject and the ways in which this can be done. By considering all these matters, I hope this book will serve as a useful introductory text in the teaching of agriculture as a whole.

C. R. W. SPEDDING

Contents

1

The Purposes of Agriculture

The first point to clarify is: 'What is agriculture?' Of course, there is general agreement about the sorts of things, people, plants and animals that can be called agricultural, but this is not good enough if we are seriously interested in topics such as the role of science in agriculture, the role and importance of agriculture in the world and how agricultural efficiency can be improved.

Not many attempts have been made to be more precise and it is quite difficult to arrive at a definition that is both useful and specific. Incidentally, there are many useful 'umbrella' terms that can and do cover a multitude of different things and their usefulness may be reduced if they are too rigidly defined. 'Competition', 'growth' and 'animal' are examples. The only satisfactory definitions are very broad and do not really exclude everything that does not strictly belong; stricter definitions, on the other hand, exclude things that one wishes to include. The best solution in these cases is to attach strict definitions to classified or qualified groups *within* the big category. Thus, 'growth in length' is more specific, as is 'competition for light': 'cold-blooded animal' or, for example, 'unicellular animal' both become more specific by the use of an adjective.

However, it is a worthwhile and challenging occupation to try and define anything we wish to discuss, provided that we remember to make the definition a useful one. By 'useful' is meant that it enables us to distinguish between the thing defined and other things; in this case, to distinguish 'agricultural' from 'non-agricultural' things.

Agriculture itself is clearly an *activity* and, furthermore, it is an activity of Man. If you disagree with this, you have to include the fungus growing carried out by certain ant species (about 100 species of Myrmecine ants and some species of termite (*Termes* spp.)) and argue that it is the activity that matters and not who is doing it. Well, why not? On balance it seems to me

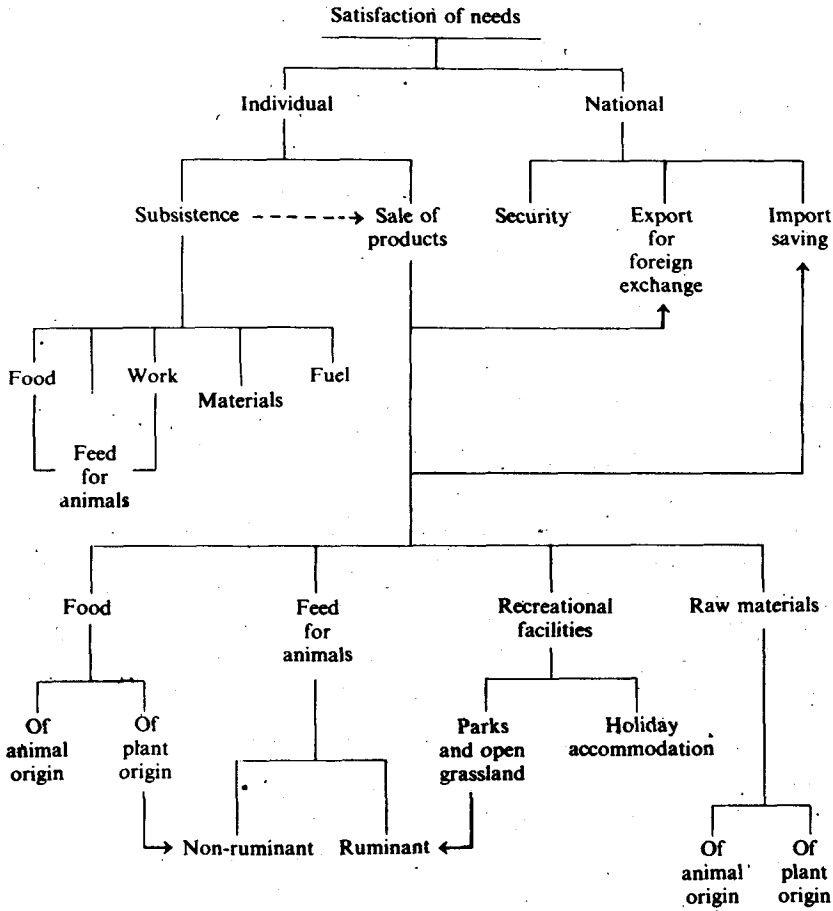

FIG. 1.1. The purposes of agriculture.

slightly more useful to limit it to activities of Man—in which case the ants are engaged in an activity similar to agriculture—but it could easily be argued that activities are independent of the name and nature of those who carry them out.

What, then, is the nature of the activity? There are two main ways of establishing this: the first is to consider *why* the activity is carried out and the second is to consider what is actually (and characteristically) done.

The first question is the more difficult. Agriculture is carried out for a great variety of purposes (illustrated in Fig. 1.1) but most, if not all of them,

are associated with producing *products*. The difficulty comes when we try to define these products. They include animal and plant materials, dead and alive, some for food, some for clothing and furnishings, some for fuel (e.g. cattle dung) and some for shelter. The animals used may not be very different from those that are hunted and the plants may be similar to some wild species. Fruit trees, rubber trees and nut trees are usually included but forest trees are not: the logic of this is difficult to grasp but forestry is generally regarded as a separate subject. The simplest solution is either to exclude timber production from the definition of agriculture or to regard forestry as a separate branch of agriculture. It is still worth asking, of course, why it should be separate and whether the traditional usage is necessarily right. (You should have a view about this, either now or by the end of this chapter.)

The main products may be described as either *food* or *fibre* and they are produced by the keeping of animals and the cultivation of crops.

The second question seems fairly straightforward, therefore, and can be answered along these lines. The activities that are characteristically agricultural are the keeping of animals and the cultivation of crops. Many people would prefer to regard these as primarily land-using activities and would rather regard as non-agricultural those animal and crop production systems that appear to be divorced from the land. Thus, housed poultry and hydroponics (the growing of plants in soil-less solutions) seem less agricultural than grazing cattle and growing fields of wheat. This does not seem very logical, however, and would exclude winter housing of stock and watercress production, for example.

More important, in arriving at a definition, is to emphasise the fact that if the animals and plants are not under some degree of control, then the situation could be similar to hunting and food collection. The degree of control required in agriculture is very variable but it usually applies: (a) to the physical location of the organism; (b) to its nutrition; (c) to its reproduction and (d) to the method and pattern of harvesting, to a greater or lesser extent.

Some animals are easier to control than others and this may account for the relatively few species used in agriculture, although the same argument can hardly be used to explain the situation for plants (see Table 1.1). The main agricultural plants and animals are given in Tables 1.2 and 1.3. Most are terrestrial and the reasons for this may include problems of control in water, including the problem of controlling nutrition. It is quite difficult, for example, to control plant nutrition in the sea, because of the huge volume of water that dilutes everything added to it.

Most of the animals are warm blooded and of a fairly large size. The reasons for this presumably relate to ease of domestication and the relative usefulness of different animals to Man at the time when domestication was taking place. It seems likely that the earliest attempts at domestication would have been directed at those animals that were hunted and those plants that were gathered for food. It also seems likely that

TABLE 1.1
NUMBER OF SPECIES USED IN AGRICULTURE
(The total number of plant and animal species is vast: only higher plants and warm-blooded animals are included here)

	Crop plants[a]	*Agricultural animals*[b]	
		Mammals	*Birds*
Number of species used	1 000–2 000 (perhaps 10 000–20 000 are *cultivated*)	20–30	5–10
% of those available (i.e. higher plants and warm-blooded animals)	*c.* 0·4	0·5–0·75	0·05–0·1
Number of species of major importance	100–200	*c.* 10	*c.* 3
Number that provide most of the world's food	15	5	2

[a] Based on Janick *et al.* (1969).
[b] Based on Zuener (1963), Morris (1965), Farmer and King (1971).

domestication would have proceeded most rapidly where reproduction occurred readily. This would apply to animals that mated and reproduced in some sort of captivity or under some degree of control and to plants in which the reproductive organs were eaten and stored. In the latter case, with seeds and tubers, for example, another crop could arise by accident but in such a way that the opportunity offered would be obvious.

It may seem surprising that insects were not used to a greater extent, especially amongst peoples known to eat them, since they are relatively easy to control, feed, breed and harvest. In fact, only two insects can really be said to be 'farmed', the honey-bee (*Apis mellifera*) and the silk moth (*Bombyx mori*), neither of which are eaten.

The activity represented by agriculture is thus a purposeful one, with the main aim of producing products, and involves the controlled use of

TABLE 1.2
THE MAIN CROP PLANTS

Crop category	*Examples*
Cereals	Maize, rice, wheat, oats, barley, millet
Pulses	Bean, pea, peanut, soyabean, cowpea
Forage crops	Grass, clover, lucerne (alfalfa)
Roots and tubers	Potato, cassava, sweet potato, turnips
Leafy crops	Cabbage, spinach
Fruits	Orange, lemon, lime, olive, apple, strawberry
Oil crops	Palm, peanut, olive, cottonseed, linseed, sunflower
Nuts	Almond, filbert, pecans
Sugar crops	Sugar cane, sugar beet
Beverage, spices, etc.	Coffee, tea, cocoa, grape, perfumes, peppers
Fibre crops	Flax, jute, hemp, sisal, cotton
Fuel crops	Hardwoods, softwoods

characteristic animals and plants. A definition embracing these features might then be phrased as follows:

> 'Agriculture is an activity (of Man), carried out primarily to produce food and fibre (and fuel, as well as many other materials) by the deliberate and controlled use of (mainly terrestrial) plants and animals.'

TABLE 1.3
THE MAIN AGRICULTURAL ANIMALS
(See Table 12.1 for more detail)

Mammals	Horse
	Ass
	Mule
	Camel
	Cattle
	Buffalo
	Sheep
	Goat
	Pig
Birds	Domestic fowl
	Duck
	Goose
	Turkey
Cold-blooded vertebrates	Fish
Invertebrates	Bee
	Silk moth

TABLE 1.4
THE MAIN CROP PRODUCTS

Food (for humans)	Cereals
	Starchy roots
	Sugar
	Seeds especially pulses
	Nuts
	Oils
	Vegetables
	Fruits
	Beverages
	Flavourings
Medicines	Quinine, opium, cocaine
Fumitories	Tobacco
Masticatories	Betel nuts
Feed (for animals)	Fresh green feed (grass and forages)
	Conserved feeds (hay, silage)
	Roots
	By-products (bagasse, straw, beet pulp)
	Concentrates (cereals, oil seed cake)
Materials	
Construction	Timber
Paper	
Textiles	Cotton, hemp
Rubber	
Household goods	Cork, woven utensils
Fertilisers	Green crops
	Crop wastes
Fuel	Wood, charcoal, alcohol, methane
Industrial oils	Linseed, cottonseed, corn oil
Essential oils	Perfumes, camphor
Gums	Gum arabic, gum tragacanth
Resins	Lacquer, turpentine
Dyes	Logwood, indigo, woad
Tannins	Hemlock, oak, mangrove, wattle
Insecticides	Roterone, pyrethrum

This would exclude gardening and landscaping unless products could be described for them (such as money?) but forestry, fish farming and a number of industrial processes would be included.

The word 'primarily' implies that there are other important products and this is indeed so: the main crop and animal products are listed in Tables 1.4

and 1.5. Of course, not all crop products are directly used by Man; many are grown to feed to animals, so the 'production of food' has to include food for animals as well. Alternatively, feed† for animals can be regarded as an intermediate product, or feed production as a process that takes place *within* an agricultural system.

TABLE 1.5
THE MAIN ANIMAL PRODUCTS

Food	Meat
	Milk
	Eggs
	Fish
	Honey
	Blood
Fibre	Wool
	Hair
	Fur
	Silk
Skins	Leather
Fertiliser	Faeces
	Bone
	Feathers
	Horn
Work	Transport
	Traction

Definitions are never as permanent as they sound and there is no reason to retain one (including that proposed here) if a more useful version can be found. Furthermore, we must always be careful not to accept too readily what seems obvious.

This brings us to a common difficulty of definitions. Although a cow is obviously an agricultural animal, it is really only so when it is being used agriculturally (i.e. for food production, for example). Even accepting that animals do have other agricultural functions and roles than just food production, a pet cow is clearly *not* an agricultural animal. Similarly, there is no difficulty at all in accepting that the horse may or may not be an agricultural animal, just as is the case for land, people, plants and water.

So particular animals (species, breeds or individuals) and particular plants (species, varieties or individuals) may serve as illustrations of agricultural organisms but whether they are themselves agricultural or not

† The word 'feed' is sometimes used to distinguish 'feed' for animals from 'food' for humans.

depends entirely on whether they are embedded in agricultural (processes or) systems or not: and processes are only agricultural when embedded in such systems. This is one reason why the next chapter deals with agricultural systems and the problems of what constitutes a system and how we know when we are only looking at a part of one.

The agricultural activity itself, of course, may only be a part of, for example, national life. Similarly, the activity that we have defined agriculture to be can also be studied and taught, as well as practised. The subject studied would also be called agriculture—the study of it does not have a special word, equivalent to zoology for the study of animals or botany for the study of plants. The practice of agriculture is generally called farming and occurs most usually in a land-use context.

The term 'agricultural science' is sometimes used to describe the scientific study of agriculture but this can be rather misleading because agriculture embraces more than the contributing sciences and cannot, therefore, necessarily be studied scientifically in all its aspects. (A similar difficulty applies, for example, to 'social science'). 'Agricultural science', on the other hand, can be used to group those sciences (or parts of them) that are most relevant to agriculture.

Since agriculture is an activity undertaken by, and involving, men, however, and is carried out for productive (and profitable) purposes, it must necessarily include aspects of economics and management, as well as biology. The multi-disciplinary nature of the subject is, to many, one of its major attractions, partly because it is not confined by arbitrary boundaries and partly because it deals with real life situations, characterised, as they so often are, by being mixtures of different disciplines.

This is true even of deceptively simple examples. A cow, for example, is an animal but it lives on grass, the growth of which it affects by biting, treading, lying, dunging and urinating on it. Furthermore, it is only able to digest it because it has, in one large compartment of its stomach (the rumen), vast numbers of minute plants (bacteria) that are capable of digesting cellulose. The cow is thus a ruminant, and used as such agriculturally, and the definition of a ruminant includes the presence of plant populations in the stomach.

How, then, could a cow be completely studied by a zoologist or a botanist alone? In farming, however, the cow also costs money to purchase, house, feed and milk, and if its products did not realise more money than these production costs, farming would cease. So it would if men found the conditions of milking intolerable or cows died of disease or no-one wanted milk anyway. Many subjects are, *of necessity*, involved in, and contribute to

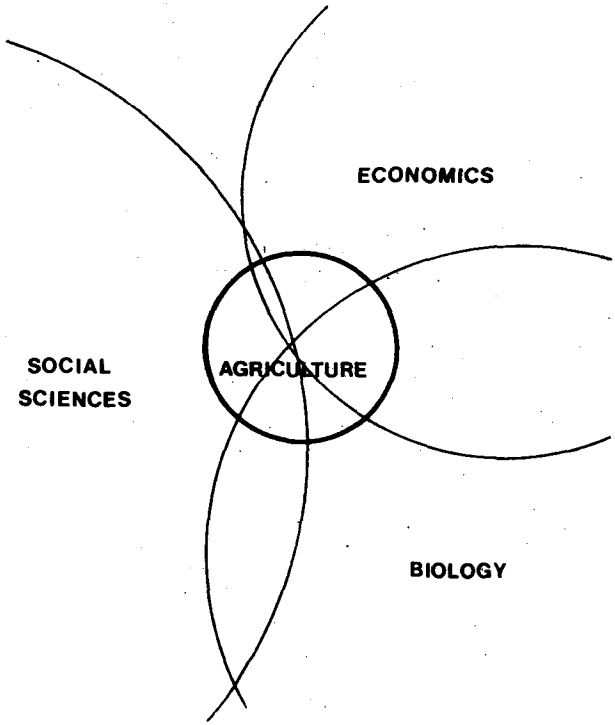

FIG. 1.2. Agriculture and the overlap of disciplines: for simplicity only three mayor disciplines are shown (overlaps with engineering, veterinary medicine and human medicine also occur).

an understanding of agriculture. The main overlaps between contributing subjects are shown in Fig. 1.2.

Agriculture as a subject, therefore, is concerned with an activity of fundamental importance to all communities and consists of a purposeful blend of science and non-science.

AGRICULTURAL MODELS

Before going on to discuss agricultural systems (the operational units of agriculture) and the models needed to describe them, it is reasonable to ask whether a picture of 'agriculture' or the 'agricultural activity' can be

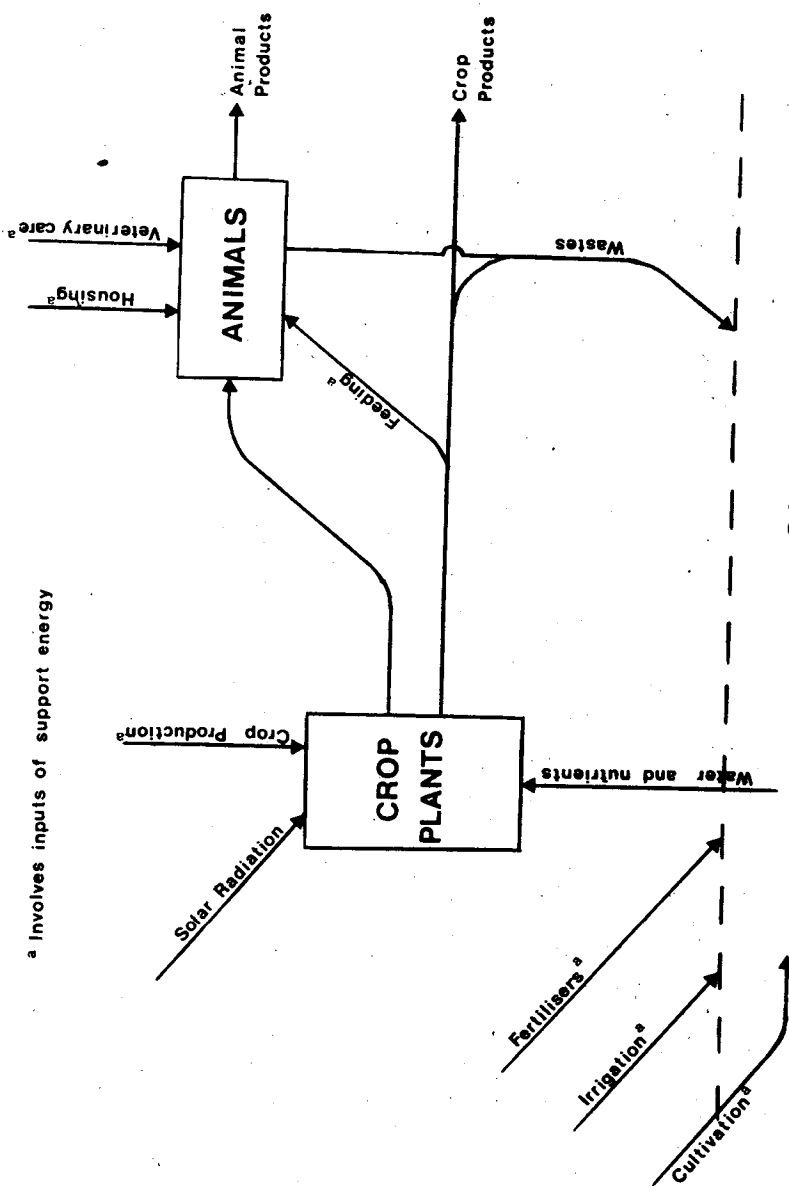

FIG. 1.3. A model of agriculture.

produced. After all, the essential agricultural activity should be describable, otherwise we cannot make or discuss propositions about it.

The purpose of such a picture is clear: it is to amplify the definition, so that we have a better, more comprehensive, more detailed and more precise description of agriculture.

Figure 1.3 is an attempt at this or, rather, at trying to convey what such a picture might or should look like. Pictures intended to illustrate or demonstrate have to be fairly simple, in order to be clear: working drawings, on the other hand, require immensely more detail and are not easy to reproduce in a visually satisfactory form. If you wanted to use such a picture for a working purpose, therefore, such as deciding what further research was needed or how agriculture could be improved, you might devise much more appropriate figures. However, many of these would only have to deal with a part of agriculture and our attempt here is to generalise about agriculture as a whole. One way of doing this has been to consider the matter historically and to trace the way in which agriculture has developed to meet human needs.

THE ORIGINS OF AGRICULTURE

It is possible to deduce some of the early developments in agriculture from archaeological remains. For our present purposes, however, it is only necessary to note that organised agriculture must have been preceded by food gathering and hunting, both of which still persist to a greater or lesser extent. Such methods of obtaining food do not allow many people to live per unit area of land (Table 1.6) and the need to increase food production clearly stems from the increased needs associated with settlement.

The cultivation of crops and the keeping of animals require considerable control over the reproduction of both, over their pests, parasites and predators, and over nutrient supplies. Many other developments must also have occurred. Various ways of using power (from wind, water and animals) would not only solve problems of cultivation, harvesting and transport, but would pose new problems, such as the invention and manufacture of equipment, harnesses and vehicles.

It does not require a great deal of thought to see how closely interwoven must have been the agricultural and non-agricultural aspects of human life during these early periods.

Gradually, however, as productivity per unit of land and per man rose, so only a small proportion of the population became essential for food