COURSE GUIDE

CRP 507
FARMING SYSTEMS

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Printed 2018, 2021

ISBN: 978-058-542-7

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INTRODUCTION

Farming Systems (CRP 507) is one semester course of two credit hours' maximum. It will be available to all students offering crop production in their final year of B. Agriculture degree. The course will consist of five units, which involves good knowledge in the natural sciences and rural sociology. What constitutes the farming system of a community or place is dependent upon the culture, soil, vegetation, climate, water availability, income, available markets and diets of the people. The decision to produce a particular crop or rare a particular livestock is the product of the man's environment. This includes the physical, biological, socio-economic environment of the farmers. Sometimes government or some funding intervention may alter or change the farmers' decision to produce. Climate change may have significant effect on the farming system of a community. In response to climate change, farmers have adapted the use of short duration crops as against their traditional long to medium duration crops. Tree crops production in some places has given way to other crops due to short falls in volume of annual rainfall that was hitherto supporting the growth of forest trees. Drastic price changes in either the inputs for production or the outputs of the farm enterprise are enough to create a major shift in inputs combination and new outputs, thus the emergence of a new farming systems of a place. This complex interrelationships (climate, disease outbreak, withdrawal of government support, changes in foreign policy of either an importer or exporter, available family labour, price changes) that come to play in the farming environment of the farmer will determine the farming systems of that community. The outcomes of these interactions and interrelationships will give rise to the various types of farming systems like pastoralist, nomadic, crop-based, forestry based, ley farming, dry season farming etc.

PREREQUISITES

Your background knowledge of rural sociology, farming systems research and general agriculture is required.

WHAT YOU WILL LEARN IN THIS COURSE

The overall aim of this course of study is to understand the farmer and his environment as it affects his livelihoods. The farmer has a family which he has to feed and ensure their wellbeing. He organises the resources available within the environment-land, water, labour livestock etc. As he combines these resources (inputs) to produce food (output), decisions are taken in such a way to go so that the chosen enterprise is sustained over time. Adjustments are made as resources and other socio-

economic variables change with a view of remaining in business at least 'at a subsistence level'.
Farming systems encompass all components of a farm enterprise, including cropland, cropping systems, livestock, common grazing land and woodlots managed by several farmers in a community and off-farm activities, within the framework of markets, land, labour, production inputs, farm products, credit and knowledge. Farming systems in Nigeria involve diverse cropping systems, including intercropping, which entails growing two or more crops simultaneously on the same field. It is common among subsistence farmers who practice low-input agriculture and those who lack adequate farm hands. There are several traditional cropping systems in Nigeria, evolving from responses to existing soil, climatic and social conditions.

COURSE AIMS

The course aims to provide you with an understanding of farming systems and types of farm enterprises available in a community and the socio-economic factors that affect the development of a sustainable farming system.

COURSE OBJECTIVES

To achieve the aims set out for this course, each unit has a set of objectives which are included at the beginning of the unit. You should read these objectives before you study the unit. You may wish to refer to them during your study to check on your progress. You should always look at the unit objectives after completion of each unit. By doing so, you would have followed the instructions in the unit. Below are the comprehensive objectives of the course as a whole. By meeting these objectives, you should have achieved the aims of the course as a whole. In addition to the aims above, this course sets to achieve some objectives. Thus, after going through the course, you should be able to:

- Understand and define Farming Systems
- Know the classification of farming systems
- List the factors that determine farming systems (physical, biological and socio-economic)
- Identify the characteristics of tropical small scale farming systems (nomadic, shifting cultivation, fallow, rotation, permanent cultivation, ley farming, intercropping, mono-cropping, sole cropping, sequential cropping, relay cropping, strip cropping,)
- What are the important crop-based farming systems (low land rice based, upland cereal based, root crop based, small scale mixed farming, irrigated small holder farming, small holder farming with plantation-perennial, crop based and agro-forestry)?

- Understand what is a farming systems research: descriptive and prescriptive

WORKING THROUGH THE COURSE

In order to complete this course, you are required to read each study unit, read relevant textbooks and references which may be provided by the National Open University of Nigeria. Each unit contains self-assessment exercises and at certain points in the course you would be required to submit assignment for assessment purpose. At the end of the course there is a final examination.

This course should take you a total of eighteen (18) weeks to complete. From the listed components of the course, you should be able to allocate your time to each unit in order to successfully complete the course on time.

In addition to spending quality time to read, I would advise that you avail yourself the opportunity of attending the tutorial sessions with your facilitators. This will give you the opportunity to compare notes with your colleagues and seek explanations where necessary.

THE COURSE MATERIALS

The main components of the course are:

1. Course guides
2. Study units
3. References/further reading
4. Assignments (TMA)

STUDY UNITS

The study units in this course are as follows:

Module 1

Unit 1 Concepts, Definition and Classification of farming Systems
Unit 2 Factors that Determine Farming Systems: Physical, Biological and Socio-economic

Module 2

Unit 1 Characteristics of Tropical Small Scale Farming Systems

Module 3

Unit 1 Important Crop-Based Farming Systems

Module 4

Unit 1 Farming Systems Research: Descriptive and Prescriptive

ASSESSMENT

You will be assessed in two ways in this course – the Tutor-Marked Assignments (TMA) and a written examination. You are expected to do the assignments and submit them to your tutorial facilitator for formal assessment in accordance with the stated deadlines in the presentation schedule and the assignment file. Your tutor-marked assignments will account for 30% of the total course mark.

TUTOR-MARKED ASSIGNMENT

CRP 507 involves a lot of reading and study hours. There are tutor marked assignments at the end of every unit which you are expected to do. You are also expected to go through the study units very carefully so that you can attempt the self-assessment exercises. You will be assessed on the different aspects of the course but only three of them will be selected for continuous assessment. Send the completed assignments (when due) together with the tutor-marked assignment form to your tutorial facilitator. Make sure you send in your assignment before the stated deadline.

FINAL EXAMINATION AND GRADING

The modalities for the final examination for CRP 507 will be determined by NOUN. The pattern of the questions will not be too different from those you have responded to in the tutor-marked exercises. However, as the university has commenced online examinations, you may have to adjust to whatever format is made available to you at any point in time. Nonetheless, you can be assured of the content validity of the examinations. You will only be examined strictly on the content of the course, no matter the form the examination takes. It is thus advisable that you revise the different kinds of sections of the course properly before the examination date.

HOW TO GET THE BEST FROM THE COURSE

The study units in this course have been written in such a way that you can easily go through them without the lecturer being physically around and this is what happens in distance learning. Each study unit is for one week depending on the volume of the unit. The study units will introduce you to the topic for that week; give you the objective(s) for the unit and what you are expected to be able to do at the end of the unit. Follow these religiously and do the exercises that follow. In addition to the above, unlike other courses where you just read and jot notes, CRP 507 has a lot of basic principles and theories to learn. You therefore need a lot of concentration while going through the course.

TUTORS AND TUTORIALS

This course has tutorial hours. The dates, times and location of these tutorials will be communicated to you as well as the name and phone number of your tutorial facilitator. You will also be notified of your tutorial group. As you relate with your tutorial facilitator, he/she will mark and correct your assignments and also keep a close watch on your performance in the tutor-marked assignments and attendance at tutorials. Feel free to contact your tutorial facilitator by phone or e-mail if you have any problem with the contents of any of the study units.

COURSE MARKING SCHEME

The following is the layout of the actual marking scheme for this course.

1. Assessments and TMAs will account for 30% of the overall course marks.
2. Final examination will take 70% of the overall course marks.

MAIN COURSE

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MODULE 1

UNIT 1 CONCEPTS, DEFINITION AND CLASSIFICATION OF FARMING SYSTEMS

CONTENTS

1.0 INTRODUCTION

What constitutes the farming system of a community or place is dependent upon the culture, soil, vegetation, climate, water availability, income, available markets and diets of the people. The decision to produce a particular crop or rear a particular livestock is the product of the man’s environment. This includes the physical, biological, socio-economic environment of the farmers. The farm is a unit and should be considered and planned for effective integration of the various crop combinations and livestock. A farm system involves the inputs, processes in their combinations and the eventual outputs with definite boundaries. He uses inputs to get outputs in response to the technical elements which is the natural resource endowment in any given location. This limits what the farming system of the locality could achieve.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain the concept of farming systems
- define farming systems
- identify the various classes of farming systems.

3.0 MAIN CONTENT

A farming system results from a complex interaction of interdependent and interrelated components of elements that bear upon the agricultural enterprises of the rural household. At the center is the farmer who decides in an attempt to achieve his aspirations, goals and desired objectives within the limits of technologies/resources available to him. He uses inputs to get outputs in response to the technical elements which is the natural resource endowment in any given location which restricts what the farming system can be. The human element provides the framework for the development and utilization of a particular farming system.

3.1 Concept of Farming Systems

The terms *farm system* and *farming system* are often used interchangeably. Here the practice is to use farm system to refer to the structure of an individual farm, and a farming system to refer to broadly similar farm types in specific geographical areas or recommendation domains. A farming system will arise from a complex of interactions and interrelationships between the farmer and his family structure, the available resources to the farmer, the market environment and other external demands on the farmer. What he produces and his combinations of resources are purely at the discretion of the farmer. The convergence of these individual decisions is central to the emergence of the type of farming system that will eventually emerge in that community or location.

A system is a set of interrelated, interacting and interdependent elements acting together for a common purpose and capable of reacting as a whole to external stimuli. It is unaffected by its output and it has external boundaries.

Farms are systems because several activities, actions and decisions are closely related to each other by the common use of the farm labour, land and other inputs required for production. In arriving on the final products to deliver, the risk elements are also considered. These include climate, price changes and government policies that will bear significantly on family welfare. What the farmer considers foremost in arriving at his final decision is the welfare and safety of his family members. On the whole, the farmer offers the framework for identification, development and utilization of a particular farming system.

The first purpose of this unit is to develop a conceptual framework for the examination of the agro-economic structure of farm-level agricultural systems.

The second purpose is to sketch the relationships among these farm-level systems, and between these on the one hand and higher-level systems on the other. These considerations form the basis for the presentation in later units of an analytical approach to farm management from a systems perspective applied in the context of the agricultural system.

While somewhat original in the comprehensiveness of its farm systems' schema, the analytical framework and approach taken are not in conflict with the approaches to systems theory and agricultural systems analysis.

3.2 Definition of Farming Systems

Agricultural farming systems are a set of strategies put in place by a farmer in response to available resources which are managed to achieve economic and sustainable agricultural productivity to meet the needs of the farm household thereby preserving the resources and maintaining the environment. Agricultural farming systems arise as a matter of necessity for the survival and wellbeing of the farmer and his household and the sustenance of the environment. An *agricultural system* is an assemblage of components that are united by some form of interaction and interdependence and which operate within a prescribed boundary to achieve a specified agricultural objective on behalf of the beneficiaries of the system.

This definition is analogous to the general definition of any *artificial* (i.e., man-made) *system* of which all managed agricultural systems (including specifically the farm-level systems) form one sub-division.

From a practical production, administration and management point of view, 'all agriculture' can be regarded as consisting of sets of systems.

3.3 Classification of Farming Systems

Systems can be classified into three broad families or divisions as either natural, social or artificial systems.

(a) *Natural systems* - those that exist in Nature - consist of all the materials (both physical and biological) and interrelated processes occurring to these materials which constitute the world and, *inter alia,* provide the physical basis for life. They exist independent of mankind. Our role concerning natural systems is to try to understand them and, as need be, make use of them. We also (increasingly) attempt to duplicate them, in part or whole; but at this point they become, by definition, man-made or artificial systems. These fundamental natural systems remain unaffected by attempts at imitation. Those natural physical and biological systems (shown in their totality as the division of natural systems in Figure 1.1) which are relevant to agriculture will be self-apparent: rock weathering to form soil; plants sustained by such soil; animals sustained by such plants ... are examples of the outward forms of agriculturally relevant natural systems in operation.

(b) *Social systems* are more difficult to define. Essentially they consist of the entities forming animate populations, the institutions or social mechanisms created by such entities, and the interrelationships among/between individuals, groups, communities, expressed directly or through the medium of institutions. Social systems involve relationships between animate populations (individuals, groups, communities), not between things. The concern here is with human social systems as they relate to or impinge upon farming, and the term social system is used broadly to include institutions and relationships of an economic, social, religious or political nature. There is a certain degree of ambiguity in defining social systems. As an example, the law of property is in its essence a social system. Insofar as it is viewed as consisting of concepts, principles and rules, it is a pure social system, independent of natural systems. But its existence also presupposes the existence of the property, including natural physical things, some of which exist as systems. To this extent, as a social system, the law of property is dependent on or subordinate to natural systems.

(c) *Artificial systems* do not exist in Nature. They are of human creation to serve human purposes. All artificial systems, including agricultural systems, are constructed from either or both of two kinds of elements: (a) elements taken from either or both of the other two higher-level orders of systems at division level, i.e., from natural and social systems, and (b) from elements which are constructed or proposed for specific use by each respective artificial system as the need for this arises.

The upper part of the system depicts the dependence relationship between natural and social systems on the one hand and between these and artificial systems on the other. The relevant relationships are:

(i) natural systems are independent of systems of the other divisions
(ii) social systems could also be viewed as being independent, but generally, a more legitimate view would be that they depend immediately or eventually on natural systems for the essentials of their material existence;
(iii) artificial systems are directly dependent on either or both natural and social systems, or indirectly on natural systems (through the dependence of social systems themselves on natural systems).

Agriculture is shown as comprising one of a very large number of actual or potential artificial systems at the sub-division level. Others are those relating to mining, transport, public health, education, etc. What such systems at this sub-divisional level have in common is that each is artificial: each is based upon or draws elements from higher-level natural and social systems; and each also contains elements that are purposefully created by some human agency to meet its needs.

3.3.1 Further sub-classification of systems

Systems within the three broad divisions or their multitudinous subdivisions can be further classified according to system 'type', a loose term but one which might be used to differentiate among agricultural systems according to several factors of which only two are shown in the sketch. As outlined below, first, the system might be either an explicit or implicit one; second, its purpose might be either descriptive or operational. Other 'type' designations could be added; e.g., operational systems could be further classified according to whether or not they are amenable to optimization.

- *Explicit systems* are those in which the constituent elements are more or less closely identified and defined, and the relationships among these elements are stated formally in quantitative, usually mathematical, terms. Agricultural scientists and economists who work with farmers are concerned mainly with explicit systems. But farmers themselves will seldom be concerned with explicit systems - only with systems of a simpler kind, or only with selected parts of such systems.
- *Implicit systems* are systems in which only the main or critical elements are acknowledged and only the major or immediately relevant interrelationships are considered. However, these elements and relationships are not formally recorded, analysed or evaluated. Farmers themselves deal primarily with implicit systems. In both traditional and more modem societies particular

agricultural systems are implied in what farmers do, or deliberately do not do. In more 'advanced' societies, farmers might formalize and work with a few explicit systems or parts of systems (farm record books, simple crop budgets, household expenditure accounts) but here also most agro-management systems will exist by implication.

The purpose in here distinguishing between explicit and implicit systems is to discourage the view that, because farmers (especially small traditional farmers) do not deal with explicit formal systems, these farmers are backward, ignorant, unsophisticated, and generally inferior as resource managers. If anything, the facts generally point to a contrary conclusion. While bad farmers can be found anywhere, any close study of small traditional farmers and farming villages in the developing world will, with patience, identify implicit systems at agro-technical, enterprise, farm, farm-household and village levels which are far more complex, sophisticated, sustainable and socially efficient than most agricultural systems found in developed countries.

- *Descriptive systems* are usually intended to facilitate an understanding of the organization, structure or operation of a productive process. This might be their sole purpose; e.g., a farmer might construct a simple input-output budget table to learn the structural configurations of some potential new crop. Depending on the results of this, he or she might then proceed to construct a more detailed budget (an operational system) to find how best to fit this new crop into his or her farm plan. At higher Order Levels an organogram describing the administrative structure of a ministry of agriculture or an extension service might be constructed or the flowchart of a commodity from farm to consumer might be drawn - these also are descriptive systems.
- *Operational systems* are constructed (by an analyst or manager or research worker) as a basis for taking or recommending action aimed at improving the performance of the system. Such systems are often elaborate. However, increased precision is not infrequently achieved at the cost of decreased practical usefulness. Thus farm managers themselves work primarily with simple operational systems, although the actual physical systems which these represent may be very complex. It is sometimes useful to recognize that, like other systems, agricultural systems may be categorized as:
- *Purposeful* or *non-purposeful* depending on whether or not they can select goals and how to achieve them.
- *Static* or *dynamic* depending on whether or not they change over time in response to internal or external influences.

- *Open* or *closed* depending on whether or not they interact with their environment.

3.3.2 The Hierarchy of Agricultural Systems

Systems of Order Levels 1 to 12 comprise the field of farm management. But systems of Order Level 1 and 2 are also, indeed primarily, the domain of the applied agricultural sciences. A further proviso is that the 'household' components of farm-household systems of Order Level 12 remain as yet not very well understood. This component is primarily the province of workers in such fields as household economics, rural sociology and social anthropology. While these various farm family-related fields are fairly well established, they have yet to be brought together comprehensively and cohesively at farm-family level to provide verified models of how rural families in the developing world think about, plan and operate the 'farm' component of their farm-household systems.

The Hierarchy of Agricultural Systems depicts the direction of hierarchical status as proceeding downward from sector to industry to village to the farm to crop, etc. But whether this direction of subordination is valid will depend on circumstances and analytical purpose. Agricultural scientists would probably reverse the order-ranking shown for the systems because, unless the basic agro-technical processes (Order Level 1 and 2 systems) are well developed, the production of individual crops will be inefficient, total farm production will be low and the agricultural sector itself will, in consequence, be an impoverished one. Similarly, extension workers might be inclined to place household systems at the top of the system's hierarchy on the basis that good farming practices (Order Level 1 and 2 systems) will not be adopted unless the household systems are working well, nor consequently will the 'higher'-order systems at industry and sector level operate at their full potential.

3.4 Nature of farm-level systems

The nature of each farm-level system (i.e., Order Levels 1 to 12) of the hierarchy may be specified from a management point of view as follows:

Order Level 1: Uni-dimensional process systems. Systems of this lowest order are agro-technical. They involve an issue or problem which for purposes of analysis or management is abstracted from the context in which it naturally or normally occurs. One example is the application of a single fertiliser element, say nitrogen (*N*), to a crop and consequent plant response to *N* in terms of crop yield *Y*. As noted previously, systems of this order are primarily the domain of physical scientists, but those systems which have practical relevance for farmers thereby also have an economic dimension and so fall within the scope of farm economics. Such simple single-dimensional systems are later examined as processes and as input-output response relationships.

Order Level 2: Multi-dimensional process systems. Systems of this second-order are also concerned with limited agro-technical relationships and again they are primarily the domain of physical scientists. They differ from Order Level 1 systems in that they take - or are defined to take - a wider and more realistic view of a subject or problem. To use the same example of fertiliser response: at Order Level 2 an agro-technical system might involve the response of plant growth or yield *Y* to not one but to several or a large number of input factors such as nitrogen, phosphorous, irrigation water, crop hygiene, soil tilth, etc. These multi-dimensional systems also are later examined as processes and as response relationships. Order Level 2 systems can be viewed as aggregations (often interactive) of constituent Order Level 1 systems.

Order Level 3: Enabling-activity systems. Systems of this order are certain enabling activities that generate an intermediate product intended for use as an input/resource by enterprises which do produce a final product. An example is offered by a legume crop turned under to provide fertility for a following (final product-generating) paddy crop. There will often be alternative ways of obtaining this resource: e.g., stripping leaves off leguminous trees, keeping cattle for their manure, or buying a bag of fertiliser. These are all enabling, resource-generating activities but only some of them, the complex ones, warrant designation as systems. They are intended to supply resources to systems of Order Levels 4 and 6.

Order Level 4: Crop systems. Systems of this order relate to the production of individual crops; but if these are primarily intended to produce inputs for other crops or livestock, they are regarded as systems of Order Level 3. On many small farms, crop and livestock enterprises produce both final products and resources.

Order Level 5: All crop systems. Systems of this order, known also as *cropping systems,* refer to the combined system of all the individual crops on a farm. On a farm with a single mono-crop, this Order Level 5 system will be equivalent to an Order Level 3 system; but on small mixed farms, there will usually be four, five, six or more different crops (of Order Levels 3 and 4) grown in some degree of combination and as many as 20 or more on the highly diversified forest-garden farms.

Order Level 6: Animal systems. These systems relate to single-species animal enterprises or activities - e.g., dairy cows, camels, fish, ducks. They are the animal equivalent of Order Level 4 (i.e., individual crop) systems.

Order Level 7: All animal systems. These systems are the aggregation of all Order Level 6 (sub)systems on a farm. Known as *livestock systems*, they are the animal equivalent of Order Level 5 (i.e., all crop) systems.

Order Level 8: Resource pool. This subsystem is a conceptual device for farm-system planning in which resources and fixed-capital services required by other subsystems are 'stored' in a 'resource pool' from which they are allocated to the other subsystems (of Order Levels 1, 2, 3, 4 and 6). The resource pool is central to the operation of the whole farm-household system.

Order Level 9: Farm service matrix. A system of this Order Level consists of all the fixed capital resources of a farm that are pertinent to the operation of the farm as a whole but are not assigned to the exclusive use of any particular enterprise or activity: land, fences, barns, irrigation channels and work oxen are common examples. Some of these capital items are true (sub) systems, having interdependence among their parts (as in an irrigation storage/delivery/distribution network, a grain drying facility, an integrated network of soil conservation structures, etc.). Some are only things (e.g., fences, a plough, a barn). But, in its totality, such capital is managed and manipulated as a system to provide general services which, while not specific to them, enable the functioning of lower Order Level systems of the farm.

Order Level 10: Whole-farm systems. Systems of this Order Level consist of all the lower Order Level (sub) systems which go to make up a farm. They consolidate in a single entity all the farm fixed capital, all the operating capital, all the final-product enterprises, all the activities and all the agro-technical processes which underlie such enterprises and activities. Structuring and managing systems of this Order Level are the main tasks or focus of farm management as carried out, on the one hand, by farmers and as investigated, on the other hand, by farm management economists in their professional capacity of providing advice to farm managers, development agencies and governments.

The terms farm *system* and *farming system* are often used interchangeably. Here the practice is to use farm system to refer to the structure of an individual farm, and farming system to refer to broadly similar farm types in specific geographical areas or recommendation domains, e.g., the wet paddy farming system of river basins or the grain-livestock fanning systems of Savannah region.

Order Level 11: Household systems. On small farms, the household itself is the most dynamic and complex of all farm-level systems, although it is a social system not an agricultural one. It dominates the agricultural systems which comprise the farm component. It has two functions: as *household* it provides purpose and management to the farm component, and as major system *beneficiary* it receives and allocates system outputs to itself and other beneficiaries.

Order Level 12: Farm-household systems. These consist of two components or (sub) systems of Order Levels 10 and 11, i.e., the whole-farm system and its associated household system, respectively. The term is a very useful if not mandatory one when used to refer to the small farms of Asia. It carries an insistence that the technical analysis discussed in the following chapters will amount to nothing at all unless it is applied to achieving the real needs and aspirations of the household might be quite a different thing from evaluating the performance of a farm system according to the subjective or preconceived ideas of agricultural technicians and economists. As the peak farm-level system, the farm-household system may be described in system terms as a goal-setting (i.e., purposeful) open stochastic dynamic system with a major aim of production from agricultural resources. These attributes are sufficient to make it also a complex system. The purposefulness of a farm-household system is ensured by its human and social involvement which enables the system to vary its goals and their means of achievement under a given environment. The openness of the farm-household system is obvious from its physical, economic and social interaction with its environment. The non-deterministic or stochastic nature of the farm-household system is guaranteed both by the free-choice capacity of its human (and, if present, animal) elements and by the stochastic nature of the environment with which it (and all its subsystems) interacts. Necessarily, a farm-household system is also dynamic under its purposefulness, openness and stochasticity which ensure that the system changes over time. Too, any farm-household system is a mixture of abstract and concrete elements or subsystems. The concrete elements are associated with the physical activities and processes that occur in the system. The abstract elements relate to the managerial and social aspects of the system.

3.4.1 Village-level farming systems

Not infrequently in parts of Africa, as also elsewhere in the developing world, the village may replace the farm-household in whole or part as the focal entity for agricultural production. Systems of Order Level 13, i.e., village or community systems, are thus often relevant to the performance of farming systems.

Order Level 13: Village-community systems. Village-level systems or community systems in some situations replace all or part of individual farm-household systems. Three situations are common. First, some production activity in its entirety, including the operation of whole farms as production units, may be on a formal cooperative or group basis. Second, only part of activity might be carried on by individual farmers while critical parts of it (such as land preparation, the supply of inputs, harvesting and/or marketing) are the responsibility of a formal farmers' club or cooperative. Third, and most difficult to analyse, is the situation found in many Indonesian villages where informal and temporary groups form to perform certain production tasks in common (such as land preparation, irrigation and/or harvesting) then disband and re-form to do different tasks on different crops, with membership continuously changing as individuals drop in and out of groups according to their interests, needs and mutual obligations. In a village there might be 10, 20 or 30 such 'cooperatives', though none might exist officially. Other examples are offered by the semi-nomadic livestock farmers of West Asia who sometimes operate as individual households and sometimes as members of a collective. In all these situations the boundaries of individual units are often so fluid and obscure that the focus for productive analysis has to be the group or village community. Nevertheless, much externally sponsored farm-development planning remains locked into the mythology of agricultural individualism; perhaps that is why on the small farms of Africa it has borne so little and often poisonous fruit.

3.4.2 Structural Elements of the Farm-Household System

The definition of an agricultural system given in this text above is a general one and applies broadly to systems of all the Order Levels. When applied specifically to a farm-household system of Order Level 12 it implies the system involves ten structural elements or components:

1) Boundaries
2) Household
3) Operating plan
4) Production-enabling resources: the resource pool
5) Final product-generating enterprises
6) Resource-generating activities
7) Agro-technical processes
8) Whole-farm service matrix
9) Structural (interdependence) coefficient
10) Time dimension.

The ten elements are briefly discussed below.

1. *Boundaries:* This first element, the boundaries of the farm-household system, set it apart from other systems and from the world at large. These boundaries are provided partly by the structural characteristics of the particular type of farm, and partly by the purpose of analysis, i.e., to some extent they are subjective and relate to more than the simple physical boundary of the farm.
2. *Household:* As previously noted, the household plays two roles: first, it provides purpose and management to its associated farm system and, second, it is the major beneficiary of its associated farm system. In its first role it provides purpose, operating objectives and management to the farm component of the farm-household system according to its broad domestic and social goals. Obviously these goals vary widely with culture, tradition and the degree of commercialisation and external influences to which the household is exposed. However, one would probably be not too far wrong in offering a generalization that the primary economic goal on smallest farms is security and the primary non-economic goal is social acceptance. If this is correct, the primary objectives for the farm are, first, production of a low-risk sustainable subsistence for primary system beneficiaries; second, generation of a cash income to meet needs not directly met in the form of food and other farm-produced materials; and third, pursuit of both of these in ways which are not in conflict with local culture and tradition.
3. *Operating plan:* The above objectives are pursued through preparation and execution of a farm operating plan. The core of this may be taken as selection of the best possible mix of agro-technical processes, activities, enterprises and fixed capital (systems of Order Levels 1, 2, 3, 4, 6, and 8).
4. *Resource pool:* This element was noted above as a system of Order Level 8 central to the management of other subsystems within the farm system.
5. *Final product-generating enterprises:* These were noted as systems of Order Levels 5 and 7 in the previous section
6. *Resource-generating activities:* These also were previously discussed as systems of Order Level 3. They are intended to supplement or entirely supply the resource pool
7. *Agro-technical processes:* These were defined above as systems of Order Levels 1 and 2. Processes may be of a biological or mechanical kind. They are a shorthand designation of all the potentially complex and interrelated physical and biological factors underlying production from crop or livestock species, only some of which may be economically relevant.
8. *Whole-farm service matrix:* This was discussed previously as a system of Order Level 9.

9. *System structural coefficients:* These coefficients identify and quantify linkage relationships (a) among the various parts or elements within each subsystem and (b) between subsystems. From the general system definition, an essential property of any system is that there may be interrelatedness between its parts. In farm-household systems (and in subordinate subsystems of lesser Order Level, particularly Order Levels 4 and 6) such interrelatedness is specified by these coefficients.
10. *Time dimension:* Unlike mechanical systems which stamp out buttons, agricultural systems rest on biological processes which occur over considerable periods - from, e.g., a few days in the case of quick-response agricides to 70 or more years in the case of growth and decline of a coconut palm. Agricultural systems are thus inherently stochastic: being dependent on the passage of time, *ex ante*, their outcomes are uncertain. Moreover, because agriculture is also a set of economic activities, the adage applies: time is money. Other things being equal, a system which yields its product or ties up resources over a short time is better than one which yields its output or occupies resources over a long time. Strictly speaking, time is not a system component; rather it is a dimension in which the system operates.

Also important from a time perspective are the sustainability and environmental compatibility of the farm system being used. If, over time, the farm system is not biologically and economically sustainable or causes resource degradation, it is to the disadvantage of both the farm household and society at large.

From our understanding of a farming system, we can further explain it to mean ‘as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate’. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions households. Farm as a unit transfers input into agricultural output and which undergoes changes over time. In the process of adapting cropping patterns and farming techniques to the natural, economic and socio-political conditions of each location and the aims of the farmers, distinct farming systems are developed. For agricultural development, it is advisable to group farms with similar structures into classes.

Broadly the classification of the farming systems of developing regions has been based on the following criteria:

- Available natural resource base, including water, land, grazing areas and forest; climate, of which altitude is one important determinant; landscape, including slope; farm size, tenure and organization; and

- Dominant pattern of farm activities and household livelihoods, including field crops, livestock, trees, aquaculture, hunting and gathering, processing and off-farm activities; and taking into account the main technologies used, which determine the intensity of production and integration of crops, livestock and other activities.

Based on these broad criteria, we will specifically classify farming system as follows:

1) Collecting from the wild

This is the most direct method of obtaining plant products. It includes regular and irregular harvesting of uncultivated plants and animals eg hunting of animals and honey, oil palm and date palm collection, locust bean and Arabic gum collecting. These off-farm activities provide extra income to the families.

2) Cultivation of crops

Types of fallow

Considerable variation and degree of intensity exists between fallow periods within a cycle. In this arrangement cultivation of land alternates with an uncultivated fallow which may take the following forms as forest fallow, bush fallow, savanna fallow, wild and unregulated ley that are common in the savanna.

Type of rotation

There is an established pattern of rotation of cropped areas with the fallow portions.

Considerable variation and degree of intensity exists between cropping and fallow period within one cycle. In some locations, the arable land is cultivated for several years and left to fallow. The period of fallow and cropping differ and depending on the length of either will give rise to shifting cultivation and permanent cropping.

Type of water supply

This is either irrigated farming or rain-fed farming

Type of cropping pattern and animal activities

This is influenced by the dominant crops and livestock activities which are dependent on the type of soil, climate, other inputs and markets.

Type of implement used for cultivation
In some locations, farmers practice zero tillage or minimal tillage while in some deep plowing and harrowing using tractors is practiced. Some farmers use hoes to prepare the land which is very common in the savannah regions and forest zones of Nigeria. Others depend on their animals to do most of the farming operations.

Degree of commercialization
1. Subsistence farming –if there is virtually no sale of crop and animal products,
2. Partly commercialized farming-- if more than 50% of the value of the produce is for home consumption.
3. Commercialized farming--- If more than 50% of the produce is for sale.

3) Grassland utilization
The utilization of grasses either cultivated or uncultivated can be used to classify the type of animal rearing in a region.

(i) Nomads
Nomads are people with no fixed home. They travel from place to place. Many nomads move as the seasons change. They move in search of food, water, and places for their animals to eat.

The word "nomad" comes from a Greek word meaning "roaming about for pasture." Some cultures around the world have always been nomadic. In today's industrialized countries, nomads are few and far between. However, there are still 30-40 million nomads around the world today!
Nomads are usually divided into three categories. There are hunter-gatherers, pastoral nomads, and peripatetic nomads. Hunter-gatherers are the oldest type of nomad.

As their name suggests, hunter-gatherers move about frequently. They search for wild fruits, vegetables, and animals that change with the seasons. All human beings were hunter-gatherers until about 10,000 years ago.

As people began farming, there was less need to move about. Today, there are very few hunter-gatherer groups. Those that do exist also farm and raise animals.

Pastoral nomads raise large herds of animals. When the animals eat all of the food in one area, they move to a new one. This gives the pastures time to grow new food.

Pastoral nomads usually stick to a specific area. The area they roam can be hundreds of square miles. They choose one spot to live in for weeks or months. Then, they set up portable, wood-framed houses called yurts.

(ii) Pastoral nomadism

One of the three general types of nomadism, a way of life of peoples who do not live continually in the same place but move cyclically or periodically. Pastoral nomads, who depend on domesticated livestock, migrate in an established territory to find pasturage for their animals. Most nomadic groups have focal sites that they occupy for considerable periods of the year. Pastoralists may depend entirely on their herds or may also hunt or gather, practice some agriculture, or trade with agricultural peoples for grain and other goods. Some seminomadic groups in Southwest Asia and North Africa cultivate crops between seasonal moves. The Kazakhs, an Asiatic Turkic-speaking people who inhabit mainly Kazakhstan and the adjacent parts of the Uighur Autonomous Region of Xinkiang in China, were traditionally pastoral nomads, dwelling year-round in portable dome-shaped tents (called *gers*, or yurts) constructed of dismountable wooden frames covered with felt. A few continue to migrate seasonally to find pasturage for their livestock, including horses, sheep, goats, cattle, and a few camels. The Maasai, on the other hand, are fully nomadic. They travel in bands in East Africa throughout the year and subsist almost entirely on the meat, blood, and milk of their herds. The patterns of pastoral nomadism are many, often depending on the type of livestock, the topography, and the climate.

Pasture refers to grass or other plants that have grown or are grown for feeding grazing animals (such as camels, cows, sheep, goats and donkeys) as well as the land used for grazing. Normadism on the other hand is a form of social organization where people move from one place to another in search of natural resources for their survival. Normadism incorporates the advantages of mobility and traditional nomadic groups were able to exploit natural resources such as grasses and water at dispersed locations in the course of their mobility.

Pastoralism is a system of land utilization which features the grazing of livestock rather than the cultivation of crops. Normadism on the other hand is the practice by members of tribes that move with their animals from place to place in search of pasture and water. Normadic refers to normads that are herdsmen in an area that leads a nomadic existence by moving their livestock around an area or region to feed on available grazing. Pastoral nomadism is thus a form of subsistence agriculture based on herding domesticated animals for their meat, hides, milk, products or item of trade.

Settled agriculture, started in about 9,000BC and pastoralism emerged somewhat later involving different people. Pastoral nomads are found in different climatic regions of the world, ranging from the equator to the Arctic Circle.

They are also found across arid deserts into tropical savannas of tall grasses on the equatorial margins of these deserts. Pastoralism as a dominant economy has developed in the old world (Asia, Africa and Europe) where numerous pastoralists herd cattle for various
Purposes. The movement of most present-day nomads is determined by the seasonal nature of rainfall and the need to find new sources of grass for their animals. Examples of such nomads include the Bendouin and Tuaregs in the Sahara Desert, the Fulani in western Africa and the Masai in Kenya.

Across the continent of Africa, several pastoral nomads herd their animals within the arid, semi-arid and savannah vegetation zones, one of these are the Fulani. The Fulani are the largest semi-nomadic group in the world found across west and central Africa. Over the years, they herd their animals across the various vegetation zones in search of pasture and water for their animals, frequently leading to conflict situations and clashes with sedentary farming communities in different countries. These recurring conflict situations and clashes have become a national security challenge particularly in some West African countries such as Nigeria.

The Fulani pastoralists/farmer's conflicts have posed serious security challenges because for decades governments at local, state and federal level have not been able to overcome the challenge. The conflicts continue leading to disruption of peaceful co-existence, destruction of properties, loss of lives and displacement of people from their homes and villages to internally displaced person's camps.

Accordingly, we have the following types of nomadic life.

1. Total nomadism – the animal owner does not have a permanent place of residence. They do not practice regular cultivation and their families move with the herds.
2. Semi-nomadism- where the animal owners have a semi-permanent place of residence near where supplementary irrigation is practiced. However, they travel with their herds to distant grazing areas every day.
3. Transhumance- where farmers with a permanent place of residence send their herds tended by herdsmen for a long period to distant grazing areas.

4. Partial nomadism is characterized by farmers who live continuously in permanent settlements with their herds remaining in the vicinity
5. Stationary animal husbandry occurs where the animals remain on the holding or in the village throughout the entire year.

SELF-ASSESSMENT EXERCISE

There are many issues confronting animal husbandry in Nigeria especially the large ruminants. Prominent among which are climate change and urbanization. Climate change forces the pastoralists to move to wetter regions, while urbanization is pushing them back. Advise the government of Nigeria on how to resolve this lingering issue of harmonious pastoralism.

4.0 CONCLUSION

A farming system results from a complex interaction of interdependent and interrelated components of elements that bear upon the agricultural enterprises of the rural household. At the center is the farmer who decides in an attempt to achieve his aspirations, goals and desired objectives within the limits of technologies available to him. Many factors influence the determination of the type of farming system in a community which is influenced by the physical, biological and socio-economic structure of the environment.

5.0 SUMMARY

The farming system represents an appropriate combination of farm enterprises (cropping systems horticulture, livestock, fishery, forestry, poultry) and the means available to the farmer to raise them for profitability. It interacts adequately with the environment without dislocating the ecological and socioeconomic balance on one hand and attempts to meet the national goals on the other. A farming system is a unique and reasonably stable arrangement of farming enterprises that a household manages according to well-defined practices in response to the physical, biological and socio-economic environment and following the household goals, preferences, and resources. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions households.

6.0 TUTOR-MARKED ASSIGNMENT (TMA)

1. Define Farming Systems.
2. Mention the criteria you can use to classify farming systems.

3. How do you use the degree of commercialization to determine the type of farming system of a community?

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UNIT 2 FACTORS THAT DETERMINE FARMING SYSTEMS: PHYSICAL, BIOLOGICAL, AND SOCIO-ECONOMIC

CONTENTS

1.0 INTRODUCTION

How profitable is the farm? The answer depends upon the choices a farmer makes about what crops to grow and where what technologies to use, and many other short- and long-term management decisions. A variety of constraints play into farmers' decisions, including constraints concerning available production technologies, biophysical or geophysical constraints, labor and input market constraints, financial and credit constraints, social norms, policy constraints, and constraints to knowledge or skills.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- identify the physical factors that influence farming systems
- identify the biological factors that influence farming systems
- mention the socio-economic factors that influence farming systems.

3.0 MAIN CONTENT

There is one thing that is central in the decision-making process of a farmer. In particular, farmers tend to pursue activities that increase their income, reduce their financial and physical risk, and reduce labor requirements. A variety of constraints play into farmers' decisions, including constraints concerning available production technologies, biophysical or geophysical constraints, labor and input market constraints, financial and credit constraints, social norms. Biological and geophysical factors and input and output market conditions are important variables that also impact farmer decision-making and adoption of land-use practices or technologies. Biological and geophysical factors that influence production can include water availability, soil fertility, risks of floods, droughts, frost, pests, or weed infestations. The importance of each of these factors varies with the types of crops planted. Input market conditions can shape farmer production decisions in several ways; dynamics of local and seasonal labor availability may mean that it is not profitable to grow a crop with a very narrow harvesting window in a month where the overall demand for agricultural labor is high in the region. All these interplays influence the type of farming system in a geographical location.

3.1 Factors That Determine Farming Systems

Factors that determine the type of a farming system in a place can be grouped into natural and socio-economic factors. The natural factors are comprised of physical and biological factors.

3.1.1 Physical factors

These include all external conditions and influences affecting the life and development of an organism. Topography, soil, and climate are the major physical factors affecting farming systems.

Topography/Relief – Topography relates to how difficult it is to till the land, soil erosion, and poor transportation networks and facilities. Agriculture can be mechanized depending on the topography of land to be used. It’s impossible to use farm machinery on sloppy land or rough, hilly slopes. Mountain slopes can be terraced in areas with high pressure on soil such as China.

3.1.2 Climatic factors

Climatic factors such as light, water, and rainfall, temperature, air, relative humidity, and wind also affect farming in various ways. Just like other abiotic elements of environmental factors such as soil and topography, they influence how crops grow and develop.

Light – Light is critical in plant photosynthesis (the process of manufacturing food in plants as sugars) and chlorophyll (the green pigment in plants) production. Light also influences phototropism, mineral absorption, stomatal movement, translocation, photo morphogenesis and abscission. The intensity (degree or level of light brightness a plant receives), quality (specific light wavelengths) and day length (the duration plants receive light in a day) of light affect plant growth and development.

Water and Rainfall – Water promotes animal and plant life. The availability of water affects crop growth and development, and thus yield. Water irrigation can double farm yields, increasing the number of crops grown in a single year. However, different crops require varying amounts of water to grow and develop. Water and rainfall determine the specific vegetation type that dominates and grows in any specific location. Therefore, they affect the growth and yield of crops.

Temperature – Temperature is the degree or level of coldness or hotness of a substance, expressed in centigrade (C) or degree Celsius and degree Fahrenheit (F). It affects various growth processes in crops such as seed dormancy breakage, photosynthesis, transpiration, respiration, protein synthesis, seed germination and translocation. Plants mature earlier in hot areas with high temperatures because photosynthate translocation occurs faster.

Extremely high temperatures limit the growth and development of crops. For example, low soil temperature inhibits water absorption because water is less mobile and more viscous with less permeable plant protoplasm. Furthermore, water solidifies and expands if temperatures drop below freezing point, rupturing plant cell walls.

Air – Air in the troposphere comprises 21% oxygen, 78% nitrogen, and 1% argon gases, including carbon dioxide and traces of other gases. Crops require oxygen during respiration to produce energy used in different plant growth and development processes. During photosynthesis, plants require carbon dioxide to manufacture food.

Relative Humidity – The temperature of air determines the amount of water vapor it can hold. Warm air can hold more water vapor than cold air. Whenever there is a 10 ^{o}C decrease in temperature, the amount of water vapor the air can hold reduces by almost half. Relative Humidity (RH) is the amount of water vapor the air can hold at any given temperature. Air humidity is 5% in humid tropical areas and 0.01% in the frigid poles.

RH also affects crop propagation. Bare root seedlings and plant cuttings are enclosed in plastic bags to prevent desiccation. Leaf and stem cuttings are also kept in plastic tens and propagation chambers to increase the relative humidity in the air.

Wind-Wind is moving air resulting from differences in heating and pressure gradients. The movement of large masses of air and the jet stream flow make up a global scale of air movement. Local air movement is small in scale. Less turbulent and lower surface winds occur at night because there is no heat from the sun.

Air promotes pollination, hence fruit and seed development. However, strong winds can foster water loss and toppling or lodging of crops. Eventually, strong winds hamper plant photosynthesis due to little or no carbon dioxide diffusion into leaves when stomata partially or fully close. Therefore, strong winds could result in poor crop growth and yield.

Soil – Crops thrive in rich, loamy soils with proper drainage. Crops absorb food and water through their roots from the soil. They also enjoy plant support. Soils with poor texture and harsh chemicals are low in productivity. Therefore, poor soils inhibit plant growth and development.

3.2 Biological factors

The biological factors do influence the farming systems of a place both crops and animals. These do not exist in isolation from climatic factors and other physical factors. The type of climate (rainfall, temperature, humidity, sun shine, etc) influences the type of crops and animals that exist in such locations. These biological factors include:

- Crops
- Livestock
- Weed
- Pests
- Diseases

The types of crops grown in a place, the animals (livestock) available, the types of weeds, pests and diseases prevalence in a location tend to greatly determine the types of farming systems of those communities.

Biological activities in the soil are important in the processes of achieving the productivity and sustainability of rainfed farming systems. These activities involve macro, meso and micro-fauna and microflora, which decompose the shoot and root residues of plants and influence plant performance. Figure 6.1 shows the components of this population of organisms and how they interact in a food chain or web to affect plant growth and losses of nutrients from the system. The optimum functioning of the majority of biological processes requires a balanced interaction between different components of soil biota both within and between major groups. The activities of all organisms and processes are affected by levels of soil organic carbon, moisture and temperature, in addition to a variety of other soil and environmental factors.
In most rainfed cropping regions, soil moisture supply and temperature can determine the populations and activity of soil microflora, microfauna and macrofauna.

Most soil microbes require carbon as a source of energy; therefore, carbon inputs through plant shoot and root residues have a major influence on their populations and the biological processes they mediate. The composition and activity of beneficial and pathogenic microbiota are affected by plant type, available soil moisture and carbon levels. Thus benefits from biological functions are maximised if management is crop-specific, especially in water-limited environments.

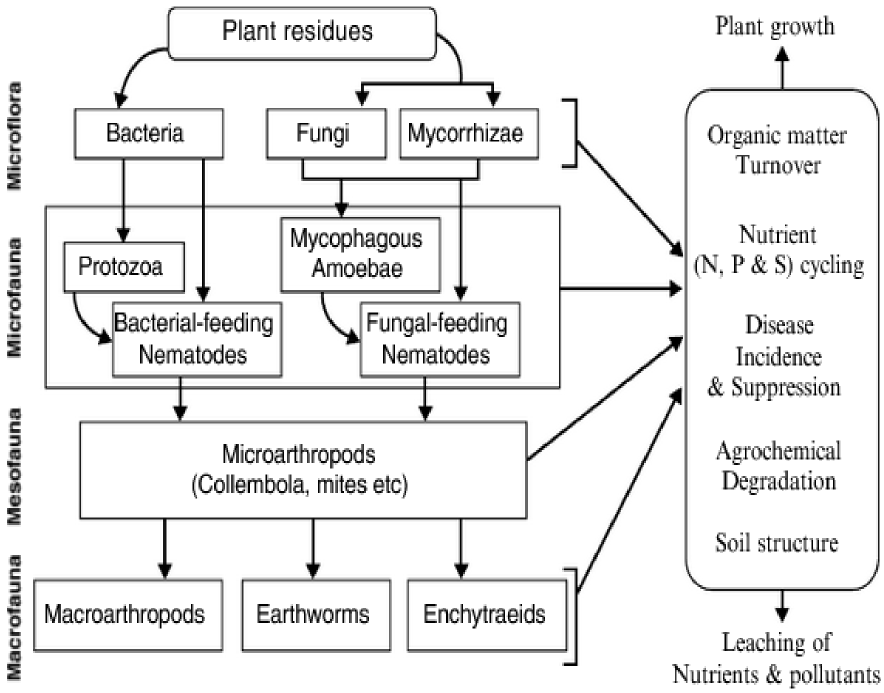


Fig 1: A detritus food web showing linkages between the different groups of soil biota, and indicating their role in soil biological functions of cropping systems

Source: Vadakattu, G. Rovira, A. and Roget, D. (2011)

3.3 Socio-economic Factors

As emphasized in the previous units, the semi-arid tropics are currently in crisis, not only in terms of current agricultural productivity but also in the prospects for sustainable agricultural development. Recently, rainfed agricultural development has been assigned high priority in the plans of many African and Asian developing countries and it continues to enjoy an important place on the development agenda of many African countries.

Of the many interacting factors contributing to the current crisis, two are fundamental. First, much of the semi-arid tropics (SATs) is characterized by soil and climate not conducive to agriculture. Secondly, the human populations of the SATs have increased rapidly in recent years, thus intensifying the pressure on agricultural resources.

This chapter aims to analyse the socio-economic aspects of sustainable agricultural development, both in general and concerning farming systems in particular. The socio-economic analysis focuses on four key areas:

1. In many cases, government policies and international markets have, directly or indirectly, reduced the incentives for agricultural production in the SATs so contributing to stagnation.

2. In general, there has been limited success in developing technologies to improve the productivity of semi-arid agriculture.
3. The limited capacity of the non-agricultural sector to provide alternative employment for the increasing population of semi-arid areas.
4. In the absence of technological breakthroughs or favourable policy incentives, the increasing population pressure on semi-arid agricultural resources has created a crisis in the development of sustainable agriculture.

The discussion that follows relies on three main premises:

1. It is essential to understand the reasons for the current situation to devise reasonable, practical strategies for improvement.
2. Farmers must be intimately involved in the diagnosis of the problems and in devising improvement strategies.
3. Agricultural technologies and policies (and support systems) are complementary means of improving agricultural productivity and sustainability.

3.3.1 Schematic representation of some farming system determinants

A farming system has three overlapping sub-systems that explain the socio-economic dimension. The combination of production processes (crop, livestock and off-farm activities) is the farming system, the environment in which farm households make decisions has biophysical and socio-economic elements.

The biophysical elements, dealt with previously, determine the physical potential, and constraints on, livestock, tree, and crop enterprises. The socio-economic elements include exogenous and endogenous factors.

Exogenous factors are those largely out of the control of the individual household such as:

(a) community institutions, including structures, norms, and beliefs;
(b) support services and policies, related to extension, credit, input distribution systems, markets and land tenure; and
(c) non-institutional factors, such as population density, location and infrastructure development.

Endogenous factors, on the other hand, are those that the household manages to some degree, including land, labour, and capital.

These inputs and managerial abilities differ for each household to affect the performance of its farming system. The household is at the same time production and a consumption unit. Farming systems are embedded in multi-level agricultural systems. Two higher systems levels relevant to this discussion are community systems and the national agriculture sector. Decisions on agricultural resource management are made at all three levels. These interact, for example, sector policies and programmes influence community decisions. These in turn influence household choices. Influences too can work the other way.

The extent to which a farming system fulfills the household goals depends, amongst other things, on managerial skills and, in most semi-arid areas, considerable luck with the weather and other uncertain environmental elements outside household control.

The dynamic aspect of farming systems should also be noted that the current farming systems reflect the cumulative interaction of the biophysical and socio-economic elements over time.

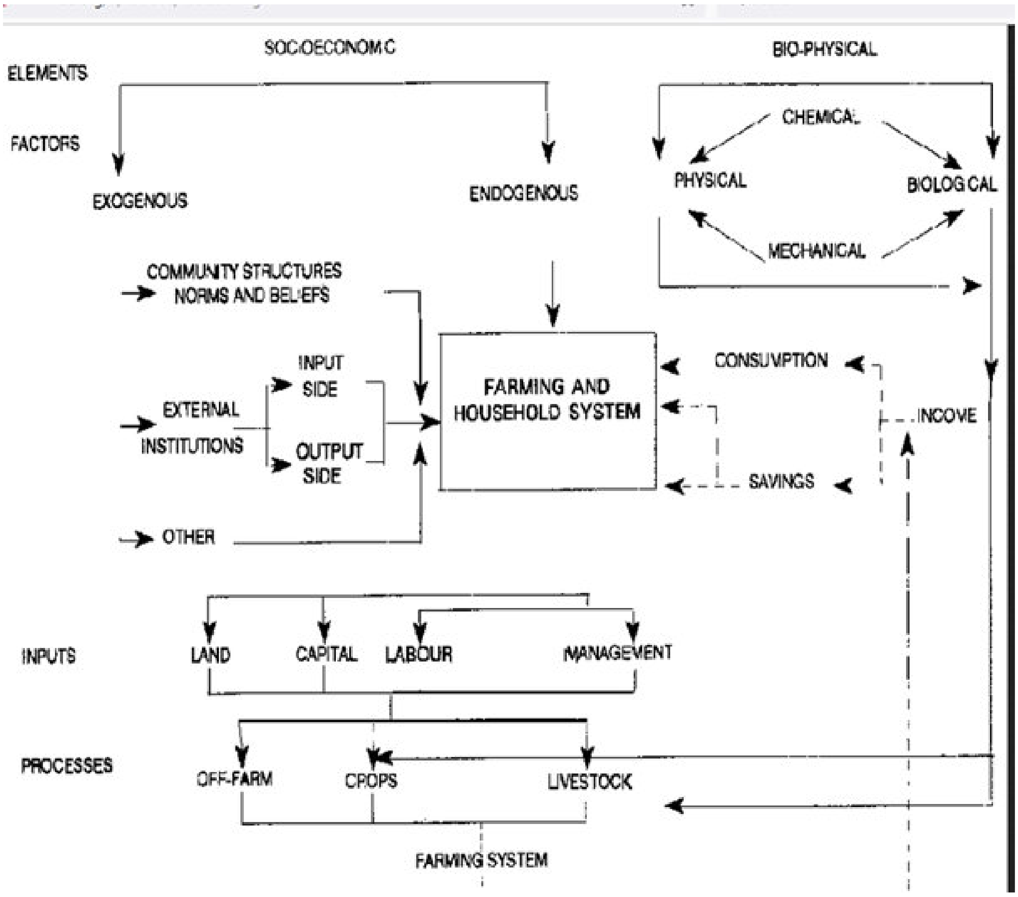


Fig.2: Schematic representation of some farming system determinants

Source: Norman, *et al* (1982)

3.3.2 Factors influencing farming systems

The conceptual framework above is a convenient way of structuring the discussion on trends and constraints relating to current farming systems in the semi-arid tropics. Though the socio-economic or human dimensions are emphasized below, the decisions and actions of households are also conditioned by their unfavourable biophysical environment.

3.3.3 Households in the Semi-Arid Tropics (SATs)

Development workers define a rural household as a group of people who live together and eat from the same pot, that is, they share the same hearth. Members are usually related. Some points related to this definition with particular reference to the SATs are:

1. Semi-arid farm households cultivate mainly using their labour and only small amounts of capital.
2. Individual household choices are often limited by external forces, including community decisions.
3. Household economies are often in transition from traditional systems to 'partial engagement in markets which tend to function with a high degree of imperfection'. Thus, it is not surprising that there is sharing and reciprocity between such households.
4. Households in transition consume a proportion of their produce, which gives them some ability to survive independently of the larger economic system.

The goals of farm households, particularly in unfavourable environments like the SATs, are not always easy to identify. It seems, however, that most wish to earn as much as possible with the least effort and risk. Some studies on the goals of farm households and farmers' attitudes to risk and uncertainty have been undertaken in the SATs. There is substantial indirect evidence that farmers like to avert risk by the practice of mixed cropping and crop and livestock diversification. In recent years, it has been increasingly recognized that individual farm households are not usually a simple decision-making unit with a single utility function that represents the joint welfare of its members. This has increased the realization that intra-household relationships influence economic behaviour.

Four points to note about intra-household relationships in the SATs are:

1. Internal relationships become particularly important where there is a high degree of congruence between the production and consumption units. They are also important where some

imperfection exists in terms of integration with the factor and product markets.
2. The economic role of individuals within households often differs. For example, men and women may have quite independent income streams.
3. Male and female labour cannot be freely substituted one for the other. Division of labour constrains its seasonal availability, the responsiveness to price changes, and influences the composition and volume of farm output.
4. Increases in household income do not usually benefit all household members equally. Technological innovations tend to disadvantage women relative to men.

Understanding the goals of households and their members is important when designing relevant strategies to improve agricultural productivity and sustainability in the SATs. Knowledge of their attitudes towards risk and uncertainty and the degree to which they are integrated, or are willing to be integrated into the market economy, is a key input in designing such strategies.

3.3.4 Communities in the Semi-Arid Tropics (SATs)

In the Semi-Arid Tropics, communities often manage the common property (and resources) and take mutual steps or to preserve the environment. Though households in a community vary in wealth, there are often patron-client relationships that provide a safety net for the poorest. On the other hand, individualistic behaviour is often sanctioned, including the adoption of modem technologies. Isolated and inaccessible communities are generally less integrated into the factor and product markets so they tend to be more influenced by community structures, norms, and beliefs. Such influences weaken with increased contact with external institutions, for example, greater dealings with the factor and product markets and with government bureaucracies. In this way, sanctions, against the individualistic behaviour of households, crumble. The probability of increased differentiation and exploitation in society increases, and the potential of community-inspired systems to monitor and control natural resource management declines. These trends tend to be reinforced by population increases.

Some of the developments associated with these trends are summarized as follows:
1. Poverty is becoming individualized. New power groups in the villages (traders, money lenders), often lack the responsibility of traditional patron-client relationships.
2. There is a trend towards individualization of land tenure, though in most areas it is not recognized by law. Usufructuary rights to

the use of land are increasingly being rented, purchased, and pledged, particularly where population pressure is becoming increasingly heavy.

3. The traditional systems of communal and reciprocal labour are being replaced by labour paid in kind or, increasingly, in cash, by the job or by the day. Even the navetane system, strongly associated with the cultivation of cash crop groundnuts in Gambia and Senegal, is becoming increasingly monetized.

Despite rapid social changes, traditional hierarchical structures still influence village life so village leaders should be involved in the introduction of agricultural change. It is important, however, that inequalities in living standards within a village are not increased by reinforcing traditional social power with newly-attained economic power.
Unless the government makes explicit efforts, common property resources are likely to deteriorate and not be managed for the benefit of the community as a whole. However, it is argued later that community action, control, and regulation need to be increasingly emphasized in strategies to protect common property resources (including grazing land, woodlots, wildlife, water) and in controlling degradation and erosion.

3.3.5 Effects of support services and policies

Support services and policies generate incentives for resource management and agricultural production by farm households. A historical perspective helps explain the type and organization of central institutions in the countries of the SATs.

The policy has had significant influences on semi-arid farming systems in Asia. In China and Mongolia, strong central control led to a surprising uniformity of farming systems until recently. With the introduction of the individual household responsibility in China some 15 years ago, farming systems began to adapt to reflect local resources and other circumstances including market liberalization.

In India, major Government programmes have influenced some farming systems in the SATs. These include the National Watershed Development Programme and various employment guarantee schemes which have propped up farm incomes during drought periods. Differently, the promotion of well and tank irrigation has re-oriented many rainfed farming systems around small concentrated areas of irrigated land and cash crop production. Another policy change with wide impact has been the liberalization of grain trading between states. The recent coordinated effort to improve oilseed production, under the leadership of the Technology Missions for Oilseeds, has been a classic success for commodity research and development. An interesting byproduct is the adoption of improved crop rotations and cultivation practices for other crops.

In Africa, the different colonial experiences of the Francophone and Anglophone countries have left their mark. Both have much in common, such as commodity-based research programmes, a bias towards research on cash crops during the colonial era (and, to a lesser extent, in the post-colonial era), a general pre-occupation with agricultural productivity issues, and institutionally weak relationships between the social and bio-physical sciences. The differences, however, are more striking. The link, for cash crops, between research and implementation (including extension work) has been much stronger in Francophone countries, where support systems have been strongly coordinated concerning individual crops (e.g., groundnuts in Senegal and cotton in Mali).

In general, commodity-based implementation programmes have been less common in Anglophone countries. Consequently, yields of cotton and groundnuts have tended to be larger and there has been greater use of oxen in Francophone countries.

In the 1970s, the popularization of integrated rural development projects embracing both food and cash crops brought about convergence. A major success story of the last 15 years has been the widespread adoption of an improved maize variety in traditional sorghum and millet area in the wetter part of semi-arid Nigeria. Similar progress has been witnessed in Kenya.

The reasons given for the widespread adoption are:
(a) a maize variety that is very responsive to fertiliser
(b) good infrastructural support (good road systems, establishment of integrated agricultural development projects, heavily-subsidized fertiliser, a ready market for the maize); and
(c) the fact that it has become food as well as cash crop for the producers.

One of the results is that this cash-earning, land-intensive technology has brought widespread use of animal traction, alleviating seasonal labour bottlenecks. Similar secondary effects have also occurred with the adoption of land-intensive technologies for groundnuts and cotton in Senegal and Mali.

Two major objectives have influenced the choice of food policies by African governments in recent decades, particularly in Francophone countries, namely:

- The encouragement of exports of cash-crops to provide much needed foreign exchange
- The political desire to provide cheap food for the towns.

In general, however, neither approach has met with much success. During the 1980s, exports of cash crops have suffered not only from overvalued exchange rates but also from declining terms of trade on international markets. At the same time, 'cheap food' policies generally acted as a disincentive as far as food production was concerned. Support systems to encourage food production, at least in the African SATs, have rarely been effective.

As a result of increasing pressures for structural adjustments, there has been a trend to allow free market forces to operate. Likely, the terms of trade for the traditional food crops of SAT Africa (millet, sorghum, and cowpeas) will continue to decline relative to those of the crops that are preferred when incomes go up (rice, wheat, and maize). It seems, therefore, that recent increases in agricultural productivity have occurred despite the increasing role of external institutions, and not as a result of their positive influence.

Apart from soil conservation programmes to combat soil erosion and some production-oriented development programmes, particularly in the Francophone countries, relatively few programmes have been implemented with domestic funding to encourage sustainable agricultural development. The Indian National Watershed Development Programme is one exception. Botswana, which is financially prosperous compared to most, is another of the few countries in the SATs with an approved soil conservation strategy. There are, however, even here few links between policy/support systems designed to encourage improvement in agricultural productivity and those designed to ensure sustainable agricultural development. This must be put right if relevant strategies to encourage sustainable agricultural development are to be developed and implemented.

Evidence is emerging from low-income countries that reducing trade restrictions and freeing prices (that is undergoing a structural adjustment process), not only encourages economic growth but reduces poverty and by doing so, reduces the pressure to over-exploit resources. It is believed, therefore, that freeing the market and reducing market distortions, improves the returns from agricultural activities. This is a key ingredient in implementing effective strategies to address productivity and sustainability simultaneously in low-income countries.

3.3.6 Land in the semi-arid tropics

Throughout the SATs, many farm households have only usufructuary rights to land. Such land cannot be used as collateral although, as indicated earlier, there are changes towards individual tenure as a result of increased population pressures. This is especially so in Asia and some African districts with settlement and irrigation schemes or mechanized farms.

In areas with low population pressure, the amount of land farmed has generally been a function of household size (i.e., labour force) and land quality. Traditionally, lighter soils are preferred to heavy ones, though the latter have been cultivated using irrigation during the dry season, particularly in India and to a lesser extent in Africa.

As population density increases, five significant changes are evident:

1. Farm size decreases with the result that the short-term private opportunity cost of leaving land fallow increases. Thus, new ways to maintain soil fertility become more and more important, as the length of fallow and amount of land fallowed have both decreased. However, leaving land fallow does not necessarily ensure that soil fertility is restored. In areas where cash crops are grown; the decline in fertility has been counteracted to some extent through increasing use of inorganic fertiliser.
2. Distribution of land among producers may become an increasing problem. There is some evidence that inequalities are growing, especially in Asia. Such trends have serious implications for the future and, because of the apparent increasing range of farm size, for the differentiation of development strategies to improve agricultural productivity and sustainability.
3. In much of the SATs, farms are being progressively fragmented, particularly where the Maliki law applies in West Africa. Though a degree of fragmentation has some advantages (for example, encouraging equitability in the distribution of land of different qualities, in spreading risk, etc.) it causes problems when mechanization is being introduced or soil conservation strategies requiring cooperation between neighbouring farmers are necessary.
4. Poorer quality and heavier land are being brought into cultivation. Poorer land is usually more vulnerable to environmental degradation, and heavier soils are less flexible in use.
5. The opportunity cost of soil moisture is increasing, especially for dry season irrigation. Thus, well irrigation is spreading in the Indian SATs, particularly for cash crops.

3.3.7 Labour in the semi-arid tropics

Household composition

A common trend in the SATs is that the traditionally preferred extended family unit, consisting of more than one married man plus dependents, is breaking up into nuclear or simple units of one married man plus dependents. The underlying reasons revolve around increased contact with the outside world and monetization of the economy. The rate at which this change is taking place depends on several complex interactions. The introduction of cash crops, secular education, increased off-farm employment opportunities, new settlements, and migration may encourage this breakup, although the speed at which it takes place may be tempered by the strength of the traditional hierarchical structure, the ethnic origin of the people concerned, the ownership of cattle and other factors.

Implications of such a trend in West Africa are:

- Fields farmed by a household are traditionally divided into common and individual fields. The common fields, controlled by the head of the household, provided food for all members of the household. An increasing proportion of the fields are coming under the control of other individuals in the household.
- The obligation of household members to work the common fields is decreasing, and the assurance of food from the household farm to meet subsistence needs no longer exists.
- Increased individualization of fields and the need for cash to pay taxes have both encouraged the growth of market crops

Decisions are increasingly made by individuals within sub-households rather than by the extended household head. This creates problems in introducing improved technology, especially if an extension or institutional credit programme is involved, because such programmes tend to be directed at household heads.

In many areas, the break-up of families is resulting in smaller farms, increased fragmentation of fields and younger, less-experienced household heads. Dependant-per-worker ratios are commonly increasing, giving poorer net worth and cash liquidity levels. Such trends raise questions about the appropriateness of the use of certain types of technology, for example, oxen and the question of cattle ownership. Poorer liquidity and net worth are likely to make the purchase of cattle more difficult, and ownership could entail management by herders because of labour limitations.

In Southern Africa, for example, Botswana, fragmentation of farm households has taken place and up to 30% of the households engaged in cropping are headed by women. Where senior males are linked with such households, they spend much of their time at the cattle posts, which are generally distant from the cropping areas or, more recently, increasingly work full-time in towns.

Similar trends are evident in marginal, dry, mountain areas, for example, in the hills of Pakistan where up to 70% of household income may be derived from seasonal migration to the towns. Such trends also occur on desert fringes, for example in Sindh, Pakistan, and in Rajasthan, India. The break-up of the extended family increases the vulnerability of individuals to droughts or other adverse setbacks to the farming system.

3.3.8 Total labour inputs

Farm work in the Semi-Arid Tropics (SATs) revolves around:
- Crops,
- Livestock
- Off-farm enterprises.

Because of the seasonably of agriculture, in many areas where population densities are relatively low, labour rather than land is the greater constraint to expansion of production. In Asia, in contrast, land has been relatively scarce in the SATs for at least a generation, so farm size tends to be determined by land availability rather than seasonal labour peaks.

The major labour input on the household farm tends to be provided by household members. In West Africa, these are often male adults in contrast to Southern Africa and Asia. Reciprocal and communal labour have slowly given way to a significant level of contract and wage labour.
The total annual work done by household members often appears to be rather small mainly because of seasonally of cropping. Typically, the coefficient of variation for monthly labour inputs increases as one moves into the drier parts of the SATs.

3.3.9 Seasonality

Although the allocation of labour to crops is particularly seasonal, household livelihood strategies tend to spread labour demand over the year. For example, during the dry season, livestock absorbs considerable labour for watering and grazing, and off-farm work is emphasized. Attempts to increase the productive use of labour during the dry season include cultivation using residual moisture or irrigation; and the traditional response of short-season migration. In parts of Southern Africa, for example, Botswana, where rainfall amounts and its dependability both between and within years tends to be unreliable, less effort is made to synchronize seasonal activities. The diverse activities related to crops, livestock and off-farm employment tend to be undertaken independently.

Seasonal labour bottlenecks are characteristic of the SATs and can critically influence the level of agricultural activity of a household throughout the rest of the year. They are influenced by several factors including: the significance of timeliness in operations, the length of the growing season (the shorter it is, the more peaked its labour activity), the type of technology employed, and the power source used. At risk of oversimplification, the following generalizations appear to apply in a West African context:

- Where only hand labour is available, weeding is often considered to be the most demanding operation.
- Introducing improved technology (for example improved seeds and fertiliser) without changing the power source shifts the bottleneck from weeding to harvesting the increased yields.
- A change from hand to animal power, using indigenous technology and ridging equipment, accentuates the wedding bottleneck, and, under certain conditions, the harvesting bottleneck.
- Combining animal power with ridging, planting, and weeding equipment - together with improved land-intensive technology - tends to accentuate the harvesting bottleneck even further.

Farmers use various strategies to alleviate labour bottlenecks. Some well-established ones are:

(a) working more days and longer hours per day on farm work at busy periods;
(b) reducing time spent on off-farm work;
(c) using more women and child labour;
(d) hiring labour - though of limited potential, this tends to increase as population density rises
(e) growing crops in mixtures.

Unlike India the African SATs tend, generally, not to have landless labourers in rural areas. The opportunity cost of hired labour, which comes from other farming households, is therefore high. Such labour is often offered because cash liquidity levels are low (Matlon 1977). Thus the negative effects of labour bottlenecks in Africa are probably greater than in India. In India the effects may be positive because bottlenecks employ landless labourers.

Turning to Southern Africa, where animal draught (cattle or donkeys) is traditional, timeliness of ploughing and planting is critical in ensuring operations are undertaken under good soil moisture conditions. This is important in ensuring good stand establishment. Row planting combined with inter-row cultivation using animals is a major advance from the broadcast and hand weeding system traditionally practiced.

Seasonal labour bottlenecks have implications when developing strategies to improve agricultural productivity and sustainability. Too often, strategies aimed simply to maximize production per unit area or to increase the area cultivated have led to development of inappropriate technology, that accentuates seasonal bottlenecks.

Use of animal power to alleviate specific bottlenecks has been most common, but chemical methods (herbicides) and biological improvements (including new varieties and practices) are still in their infancy. The importance of improving labour productivity at busy periods is illustrated by the fact that the marginal productivity of labour at such times can be as much as three to four times higher than the wage rate. Thus, although water availability and soil fertility may be the major physical constraints on soil productivity and sustainability throughout the SATs, strategies to improve them are unlikely to succeed unless they are compatible with increasing the productivity of labour at times of seasonal bottlenecks.

3.3.10 Capital and cash in the semi-arid tropics

Apart from livestock, the capital of small farm households consists largely of goods produced by them directly, such as hand tools, grain stores, etc. Consequently, capital tends to be small. As population density and land use intensity increase, capitalization tends to increase. With the introduction of improved technology, capital tends to increase further and change in character, enabling farmers to buy items such as inorganic fertiliser and animal equipment etc.

In Asia, cash has been most needed to purchase food grain in the gap before the next harvest, and for social expenditure on marriage and festivals. This contrasts with West Africa, where most explicit farm expenditures are for non-household labour. When agricultural activity is approaching its peak (June to September) cash resources are at their lowest. The introduction of improved technology is likely, initially at least, to exacerbate this. Traditional sources of credit, often obtained to buy food pre-harvest, commonly incur high implicit, if not explicit, interest rates.

Institutional credit tends to be repaid quickly only where programmes are carefully coordinated with other external institutions and support systems, particularly input distribution and product marketing. Certainly, this is true of the introduction of draught oxen systems in

West Africa to help grow cash crops (e.g., groundnuts in Senegal and the Gambia, cotton in Mali and the Gombe area of Nigeria, and maize, also in Nigeria).

In India and to some extent in Southern Africa, oxen are an integral part of subsistence farming. In West Africa, however, it is difficult to envisage millet and sorghum, which are mainly food crops, justifying the costs of oxen and equipment. Oxen have been tried in areas without a cash crop but pricing policies, particularly in Francophone countries, together with unimproved technology, have generally made such efforts futile. As indicated earlier, maize grown in northern Nigeria both as a cash crop and for household consumption, and oilseed production in India, are exceptions.

3.3.11 Cropping patterns

A wide range of crops can be grown in the Semi-Arid Tropics (SATs) despite the physical and biological limitations. The crops grown reflect socio-economic circumstances, both exogenous and endogenous, past and present. Such circumstances need to be understood to appreciate the dynamic, evolving nature of agriculture in the SATs. Understanding can help predict the future.

Crop and livestock husbandries have evolved over generations and are often adapted to the environment. Relatively recent, accelerated population increases have tended to upset the process of gradual adaptation. This highlights the need to develop relevant improved technologies to increase productivity and ensure sustainability. Many traditional practices can be used as building blocks to develop improved farming systems.

Three such practices are particularly important in many parts of the Semi-Arid Tropics**:**

1. The use of mounds etc. Whether crops are grown on ridges, mounds, or on the flat depends on many factors, including
   - rainfall,
   - availability of organic matter,
   - culture,
   - soil type, and
   - type of power used (animal, hand, etc.).
2. The 'ring' cultivation system. This system, which used to be popular in West Africa, involves the permanent cultivation of some fields, usually near the compound, where fertility is maintained by manuring. Fields farther away are cultivated for a few years, after which soil fertility is restored by fallowing. Increasing pressure on land is leading to a higher proportion of

permanently cultivated fields, and the remaining outer fields are being left fallow for progressively shorter periods. There is evidence that the total amount of manure applied increases as the proportion of permanently cultivated land rises.

3. The use of mixed cropping. Crops that are grown in mixtures in many parts of the SATs show that though yields of individual crops are often depressed when grown in mixtures, this is more than offset by other crops in the mixture, resulting in a higher return (value) per hectare.

Despite higher total labour inputs, the returns over the year per work-hour and, to a greater extent, per work-hour during the bottleneck period, are usually higher for crop mixtures than for single crops. Crops grown in mixtures at existing technological levels tend to be more profitable, whether land or labour is more limiting. They are also more dependable and are a form of rotation.

In general, traditional agricultural practices have been neglected in the development and dissemination of improved technology. The major programmes undertaken in Asia have concentrated on multi-environment on-farm testing of technologies first developed on research stations. Small-scale applications by non-government organizations are an exception to this generalization.

In African Francophone countries, where cash crops for export have been introduced and their yields substantially increased, much of the crop is grown in pure stands. This is partly because the technology was developed for sole stands and partly because of the success of the external support systems that encourage the growing of these crops according to official recommendations. Where improved technology has not been adopted and yields are less improved, such cash crops are often still grown in mixtures, for example as in Nigeria. The practice of mixed cropping still dominates food crops. In India, high-yielding varieties increase the significance of single cropping. Only relatively recently has the potential of mixed cropping using improved technology been demonstrated. This could have important implications for ensuring sustainability. It has also been demonstrated that, though the number of crop mixtures decreases with the introduction of animal traction, mixed cropping is not incompatible with animal traction.

Increased emphasis on the development of improved technologies for mixed crops appears to be justified. This is particularly so in districts where they are still dominant and in areas where the potential for sequential cropping is limited by the shortness of the rainy season.

The complementarity of cropping enterprises will be enhanced when one or more of the following characteristics outweigh the negative competitive effects between species:
(a) different growth cycles,
(b) different rooting habits,
(c) the symbiosis between species,
(d) compatible labour requirements.

Mixed cropping is most effective when the products have varied or multiple uses for both human and animal consumption. For example, in some areas, the crop residues from cowpeas (used to feed livestock) may be a more important product than the grain, which is used for human consumption.

3.4 Interactions between crops and livestock

Animals as a source of power

Livestock are often an under-estimated part of the farming system. Whilst one-third or more of household income in the Semi-Arid Tropics may come from livestock they also have multiple uses:
(a) They are a form of saving and investment
(b) A source of meat, milk, manure, fuel and other by-products; and
(c) A source of draught power.

Ownership of livestock, other than cattle, tends to be widely dispersed, both between and within households. Cattle ownership, on the other hand, tends to be unevenly distributed, being concentrated in wealthier, often more influential, households. In West Africa and, in places, in Southern Africa and the Middle East, cattle ownership and management are often separate. In West Africa management is in the hands of nomadic herders, usually the Fulbe, who also own cattle in their own right.

The potential benefits of some degree of integration between crops and livestock have been recognized traditionally in the Semi-Arid Tropics (SATs). Integration of crops and livestock can, in theory, lead to more efficient use of land unsuitable for crop production. It can provide use for crop residues and by-products, provide manure, and be a source of income, savings, and investment. In West Africa, this is so even where livestock is owned and managed by nomadic herders, and crops are grown by sedentary farmers. Such symbiosis developed in areas with relatively favourable land/labour relationships.

Increases in population density, however, have forced and are forcing changes in traditional relationships. The diminishing availability of land is resulting in conflicts between herders and farmers, and conflicts about whether resources such as labour and capital should be devoted to products for human consumption or animal production. There is concern too about declining soil fertility. It is one of the paradoxes of the ever-decreasing land to labour ratio that increasing conflicts between crop or animal production inhibit the benefits of livestock manure in preventing the decline of soil fertility.

Unfortunately, most of the land newly taken into cultivation has been prime pasture land, thus depriving livestock of a relatively sure supply of better quality fodder. This increasingly forces livestock owners to rely upon degraded common pasture (termed 'wasteland' in India) for grazing. Because of overgrazing, such common resources become heavily degraded.

The currently-developing competitive relationships need to be reversed and symbiotic relationships re-established if ecological stability is to be achieved. In the last 15 to 20 years, a major spontaneous trend has developed in the middle belt of Nigeria for many of the nomadic Fulbe to settle with their animals. Here population densities are lower than farther north. Progressive tree cutting has resulted in the southward movement of the zone in which tsetse fly become a problem for livestock.

Livestock has a key role in ecological sustainability in the SATs in the maintenance of soil fertility. The role of manure in the 'ring' system is described above. Its application increases crop yield and improves soil quality. Within the SATs, its use is quite varied and its marginal value product appears to increase with increasing population density (McIntyre *et al.* 1992). Significantly, in the most densely populated areas where the little forest is left, such as the Indian SATs, manure is collected and much is burnt as fuel. One of the drawbacks of manure as fertiliser is its bulk concerning nutrient content.

It can incur high handling costs even within a farm.

The demand for livestock feed and fodder is substantial in the SATs, but biomass production is small and unreliable. Sown pastures are not economic, but improved use of crop residues appears a possibility. As population density increases, the value of crop residues for use as fuel rises. In the case of fresh milk production, treatment of crop residues to improve digestibility appears economic. In other cases, residue treatment is not attractive. The only successful instance of urea treatment of straw for livestock fattening is in a higher rainfall zone in China.

A special case deserves mention. In Syria, traditional links between nomadic herders and sedentary farmers provides all-important manure for the latter's fields. Here the value of manure outweighs that of the crop residues removed by grazing.

3.4.1 Animals as a source of power

Animals are a traditional source of power in the farming systems of the Asian SATs. Oxen are used as cart and plow animals throughout most of southern Asia, but many small farmers do not own oxen and some are forced to exchange human labour for that of oxen. In contrast, animal traction has been used in the West African SATs for little more than 70 years. The introduction of animal traction can help increase the efficiency and productivity of human resources by the use of equipment designed to maximize the effectiveness of labour during seasonal bottlenecks. The standard idea that draught power is best used to increase the area cultivated (extensification) has been replaced, particularly in Francophone countries, by the concept of its use in intensification to increase soil productivity through manure application, deep plowing, the burial of crop residues, etc. Donkeys and horses as well as oxen are used in the SATs, particularly on lighter soils. In West Africa, animal traction is now closely linked with commercialized cropping. Its successful introduction was often linked to a particular cash crop and the use of improved technologies that give high yields per hectare. This provided the revenue to pay for the equipment and sometimes the animals. It was often complemented by a strong support system embracing an input distribution network, institutional credit, appropriate extension services, and a market for the product.

Many problems have been encountered on the way to the successful adoption of animal traction in West Africa. They include:

(a) Shortage of trained animals and operators, especially for inter-row cultivation;
(b) The weakness of draught animals caused by lack of supplementary feed;
(c) Use of inappropriate equipment;
(d) inadequate facilities for repair and servicing of equipment;
(e) The non-availability of suitable equipment;
(f) Under-use of animals during the year as a whole;
(g) Fragmented holdings that reduce work efficiency;
(h) Damage to equipment from the large numbers of tree stumps in the fields; and
(i) The lack of finance to help farmers hire draught animals. There are two further major problems relating to animal traction in West Africa:
    - Prices for cash crops have often increased more slowly than prices of animals and equipment. This has slowed the

adoption of draught animals and reduced beneficial interactions between crop production and livestock. Interactions can develop between farmers who own oxen and equipment and those who do not. Households who own draught animals can plough for those who do not and the latter can pay with labour. The potential for exploitation is obvious, especially if such labour is demanded at times when its opportunity cost is high. This will always occur to some degree, but it is most likely when relatively few households own animals. Interestingly, this does not appear to have been a problem in Botswana, where draught animals are traditional. However, those households not owning traction tend to plant late and be less timely concerning soil moisture. Consequently, their yields tend to be lower.

- Incorporation of residues by deep ploughing after harvest, the cornerstone of past intensification in Francophone countries, particularly Senegal, has not been particularly successful (Hopkins 1974). Although land intensification technologies enabled the adoption of animal traction, many farmers see the use of animals more as a means of extensification. The central problem, however, is that deep ploughing is both time-consuming and power-intensive, while the period available after harvest when the soil is suitably moist is too short for the operation with animal draught.

3.5 Other factors influencing farming systems

Although many farm households in the Semi-Arid Tropics (SATs) have undoubtedly improved their standard of living over the last 50 years, progress has not been as great as desired. Indeed, there is reason to be seriously concerned about the future. With increased accessibility to the outside world, there have been three trends with important implications when considering future action:

- Though there has been significant migration to the towns, it has been insufficient to check or reduce increasing population pressure of less favoured rural areas in the SATs.
- Because of progressive absorption into the market economy and the movement towards individual rather than shared poverty (i.e., central government rather than community control and responsibility), many farm households have become more vulnerable to drought. Consequently, annual variations in living standards have become more marked, except where incomes have been raised substantially above subsistence level.

- Another trend, also related to increased monetization and individualization of poverty, is increased differentiation in living standards within many communities. A long-standing feature of subsistence farming in many parts of the SATs, particularly West Africa, is the seasonal variation in living standards known as the 'hungry gap'. This is now more open to being exploited; food is often least available when the demands of the agricultural cycle are highest. Two important implications of seasonal hunger are:
  - ✓ Increased labour effort, except perhaps through changing the power base, is unlikely for many farm households during peak labour demand periods without an improvement of their nutritional levels.
  - ✓ The hungry gap affects the more disadvantaged households and members of society worst. With the changes from shared poverty and social power to increased individualization and economic power, poor households are becoming more vulnerable to exploitation. Another change with equally severe long-run consequences is for poor farmers to obtain credit before harvest at high rates of interest. In the Indian SATs, unlike West Africa, localized shortages do not translate into sharply rising food prices (Walker and Ryan 1990) because of the well-integrated nature and the large size of the economy combined with the fact that dry periods tend to be geographically localized.

In West Africa, households have always had a degree of heterogeneity, but laws of inheritance, a relatively egalitarian land tenure system, the availability of surplus land, traditional hand-powered technologies, and community-minded ruling elites led to fairly even income distribution. This presents evidence supporting the view that the degree of equality is inversely correlated with the degree of involvement in cash markets and also with village size and population pressure. The same study also provides some evidence that incomes derived from farming, in semi-arid Nigeria, are less variable than off-farm sources of income, though analysis of all sources of income revealed greater equality in income distribution.

The proportion of income derived from farming tends to be higher for poor households than for wealthier ones, though absolute levels are much lower. At the same time, lower-income farmers earn a higher proportion of their income as farm labourers for others than higher-income farmers. This is presumably because the poor needed cash income to overcome seasonal problems, and hired farm work is available when their need for additional income is greatest. However, the higher-income households tended to participate in more remunerative off-farm work that required some capital (e.g., trading), thus further differentiating themselves from the poor.

The trend towards increasing inequalities in income at the village level and the associated seasonal hunger that often arises is obviously of major concern. Is this avoidable? The answer is yes. Up to now, technology development has not recognized the heterogeneity of farmers and support systems have been geared towards the better endowed or more influential farmers. However, technology alone cannot be expected to solve all the problems of income distribution; the design and implementation of suitable policies will play a critical role. In the Indian SATs, the dense population and legislative threats to impose land ceilings seem to have reduced farm size and encouraged intensive use of labour and land, no matter what the farm size. On this basis, the same types of technology seem to be relevant for all farmers in the SATs, though some differentiation might be desirable when other factors are taken into consideration (for example, differentiation in terms of accessibility to support systems, cash flows, etc.).

The challenges of the SATs include the general one of identifying sustainable ways to increase agricultural productivity but also the need to recognize the heterogeneity of the farming population when developing strategies. This will enable the livelihoods of all to be improved and become sustainable in the long run. In doing so, it is important to recognize limitations other than those relating to resources, that prevent many farm households from maximizing their technical efficiency. Failure to do so will exacerbate the situation and further inequalities will develop.

3.6 Strategies to achieve sustainability

Background - Policies and institutions

It is generally recognized that environmental degradation in high-income countries usually results from wealth, over-development, and waste generation exceeding the assimilative capacity of the environment. In low-income countries, however, degradation is often associated with poverty and is caused by depletion of the resource base.

As indicated above and by many others, farmers in the SATs are compelled to modify traditionally sustainable practices in environmentally damaging ways. They do this trying to maintain their short-term standards of living, which are frequently little above the survival level.

In the SATs, rapid population growth, combined with the fact that many people still live in rural areas, creates enormous, ever-increasing pressures on an already stressed ecological environment. The challenge of attaining and maintaining sustainable agriculture cannot be met without addressing several fundamental issues, which go way beyond the relatively narrow focus of the present discussion. These issues involve the governments of SAT countries in political commitments through the vigorous support of appropriate programmes. These are well articulated in a recent document. They include programmes designed to cut down population growth rates and create employment opportunities outside the agricultural sector. Whatever happens, given the current population growth and the relatively low absorptive capacity of the non-agricultural sector, it is likely that more rather than fewer people will be trying to derive a living from agriculture for years to come.

The migration of people to less populated areas has limited potential. Even in India, with its well-integrated economy embracing several ecological zones, there has been less migration from poor areas than expected. Where migration has occurred it has sometimes been a very mixed blessing, particularly where the movement has been into even more fragile ecosystems (e.g., more arid areas of Niger) rather than wetter areas (e.g., sub-humid zone of Nigeria).

Even assuming that population expansion in rural areas can be tightly controlled, the challenges of ensuring crop sustainability are formidable. If the issues are to be successfully addressed, it will be necessary to widen the focus from simple crop sustainability to a concept of sustainable livelihoods for farm households. As indicated earlier, such households derive their living from a combination of growing crops, keeping livestock and off-farm, income-earning activities. Failure to consider the current and potential, positive and negative, relationships between these three types of activities could seriously limit both the choice of strategies that can be used and the chances of ensuring crop sustainability.

All the issues cannot be discussed here, but off-farm employment could play a key role in solving cash flow problems of farm households, and also provide income independent of the natural resource base. The more reliable such income, the greater will be the potential for relieving the pressure on the natural resources and the greater the chances of achieving crop sustainability. Indeed, there is some agreement that the demand for off-farm labour must accelerate. Unfortunately, government incentives and programs to encourage off-farm employment outside the urban areas are rare. This is particularly true for employment in the informal sector, in which most of these jobs are found. Studies show that the potential for stimulating employment in the informal sector is substantial, especially where agriculture is partly commercialized, so two-way links to the non-agricultural sector are already established.

There is a need for investment of public funds in training, etc. This needs greater attention by public authorities not only to generate employment but, by doing so, to help relieve pressure on the natural resource base. The difficulties of absorbing any population increases into the non-agricultural sector are illustrated by the relationship,

$R = P/N$

where: R represents the rate at which the jobs need to expand to absorb all increases in population,

P is the rate of growth in the population/labour force,

N is the proportion of the labour force in the non-agricultural sector.

In many SAT countries, P is often about 3% and N is often only 0.25, indicating that R is about 12% - an almost impossible task.
In conclusion, two basic points are reiterated, which are the foundation for addressing productivity and sustainability issues:

- Markets should be liberalized allowing market signals to guide the allocation of resources and product mixes. This will allow opportunities for comparative advantage to be exploited, thereby encouraging more efficient use of resources and national goals of food self-sufficiency to be replaced by goals of food security at household and national levels. Subsidies need to be given sparingly and selectively and to be designed to bring about congruence between production and sustainability. It is recognized that this is not necessarily the most desirable approach, but until full-resource, cost accounting systems can be implemented, there are few alternatives.
- Ways are needed to re-establish a degree of community responsibility, control, monitoring, and regulation of natural resources. These should include soil conservation strategies requiring community action so that the community as a whole benefits.

3.6.1 Role of livestock

Although it has been suggested that livestock should be discouraged and, if possible, eliminated from areas in the SATs, particularly those densely populated, it is obvious that such a strategy may not be feasible or indeed rational. Reducing livestock numbers or keeping them penned was advocated on page 77. One implication behind such proposals is that livestock has caused many problems. Others argue that rapid increases in human population and crop cultivation are the major causes.

Many of the inhabitants of the SATs are traditional livestock owners. Coercion to dispose of livestock is likely to meet with resistance, and incentives to do so are beyond the resources of many governments. After all, even in densely populated India, livestock remains an important component of most farming systems.

As land use intensifies and labour requirements rise, animal traction (usually oxen but sometimes donkeys) is required to deal with seasonal bottlenecks. This is despite the increased use of temporary hired labour, sometimes originating from other areas. The alternative use of tractors is unlikely to be economic, given the rapidly increasing population densities (and smaller farms) and the time-bound nature of some of the tasks in dryland agriculture. This inhibits the development of profitable contract hires or rental markets for expensive tractors.

Livestock husbandry is one sustainable use of land that is unsuitable for crop cultivation. Such use depends on improving the pasture quality while allowing some of its fertility to be transferred to cultivated land through the livestock's dung. Incentive schemes for improved livestock husbandry have generally failed, either because they required fundamental changes in the way livestock owners lived and/or because the incentives were insufficient. As an example, in Northern Nigeria in the 1960s, the nomadic Fulbe were encouraged to operate in grazing reserves, and a market was provided for the milk their animals produced. As implied above, there is, in terms of resources available to individual households, a degree of complementarity or symbiosis between crops and livestock, which would be lost if livestock were eliminated. The challenge is to try to identify attractive ways that maintain complementarity whilst allowing fundamental changes to be determined by market forces. For example, in Nigeria during the last 15 to 20 years, increasing conflicts between nomadic or semi-nomadic livestock owners and sedentary cultivators, have arisen as a result of increasing population densities. This has brought about economic incentives for many Fulbe to settle in the southern part of the semi-arid zone and the sub-humid zone. Given this situation, it is felt that more intensive ways should be sought to keep livestock through the use of legumes (both grasses and trees), fodder banks, alley farming, and living hedges. Such systems are likely to be attractive if a secure market can be developed for a product that can be regularly and readily marketed (e.g., milk for urban markets).

Similarly, in India, cattle are not only a key component of the farming system but also have spiritual significance, so development cannot proceed without fall consideration of their multi-faceted role. It is believed that livestock has a future in the SATs. There is, however, a need to identify and implement strategies that will:

- maintain the complementarity between crops and livestock in productive ways that help attain long-term sustainability. Given the human population trends in the SATs, these will undoubtedly evolve in the direction of more integrated, mixed crop/livestock systems.
- encourage both the increased commercialization of livestock husbandry and the adoption of intensification. The off-take rates for meat animals, for example, could be increased. Currently, these are often as low as 8% compared with commercial levels of 15%. In other words, market forces may be used to encourage the necessary adjustments.

3.7 Productivity with sustainability

Until recently, in most low-income countries, priority has been given to increasing agricultural productivity, in particular that of food grain. Lip service has been paid to issues of ecological sustainability, but only recently has this become the focus of donor agency support. The challenge in the SATs is to increase agricultural productivity whilst ensuring ecological, economic, and social sustainability.

Governments are preoccupied, because of the poor state of their economies, with the short-term problems of increasing production and do not have the resources or security to worry about long-term sustainability. As indicated earlier, policies often have not even encouraged improvements in agricultural productivity.

The poorer and closer to subsistence level farmers are, the greater the likelihood that their felt needs are those requiring fulfilment in the short term (e.g., producing enough food to survive until next year). At this point, we have to stress the critical nature of the relationship between food security and sustainable resource management. Only relatively rarely, where soil erosion is very severe and threatens immediate survival, will farmers be inclined to implement soil conservation measures, without immediate payoff in terms of income.

3.7.1 Agricultural productivity

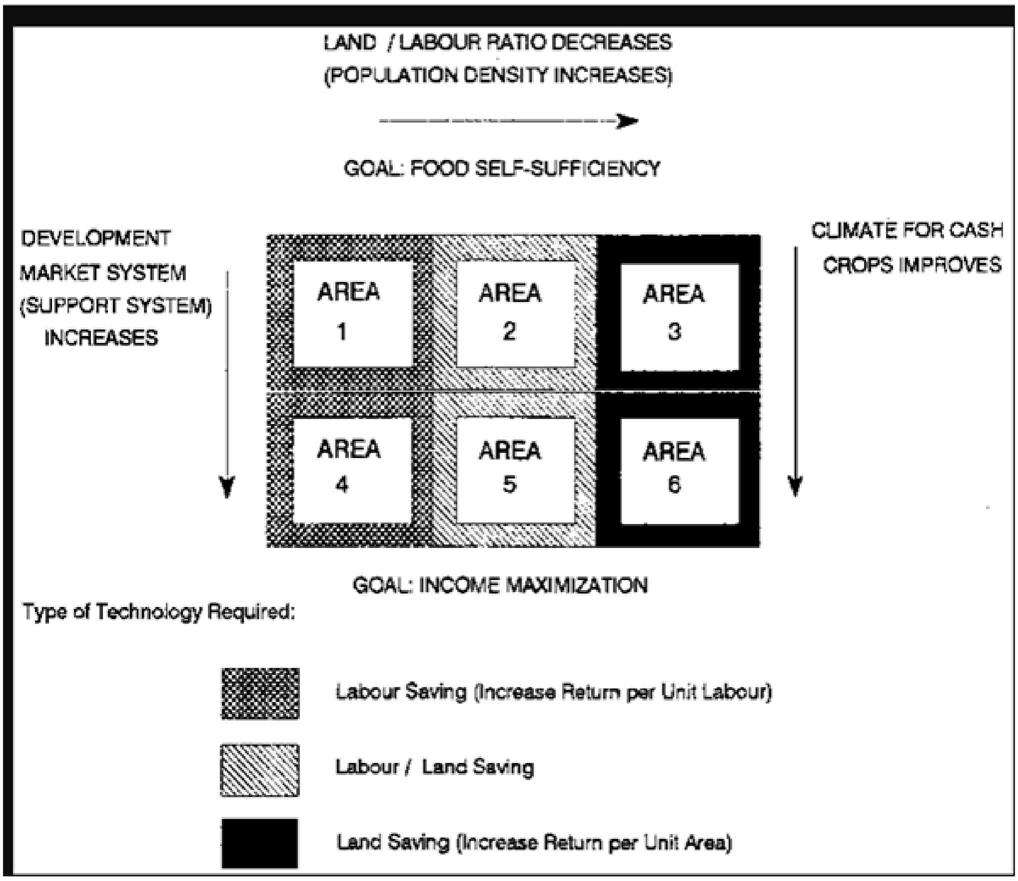
As will be apparent to anyone familiar with the SATs, the adoption of improved technologies resulting in increased output per person as land has become more limiting has been relatively rare. Population-induced land intensification without appropriate technologies to raise productivity substantially is unlikely to increase output per worker or food available per head.

The development of relevant improved technology is complicated not only by the relatively poor and heterogeneous environment in which the farmers operate, but also by social and economic factors. Figure 43 illustrates the difficult task of developing improved technologies in various parts of the West African savannah. The schematic diagram shows the relationships of five interwoven variables: household goals, market and support system development, population density, market opportunities, and primary technology development requirements.

The complexity of identifying appropriate paths for the improvement of agricultural productivity is reinforced by the following observations:

- Population density affects the emphasis. In areas of the sparse population (Areas 1 and 4), labour-saving strategies are more significant, but in densely settled areas (Areas 3 and 6), yield-increasing strategies are required. At intermediate densities (Areas 2 and 5), both technological options must be taken into account.
- Market system development, including the development of a good road and transport system, permits the traditionally important goal of food self-sufficiency to become at least partly diluted in favour of a more commercialized agriculture that involves entering the marketplace (i.e., food security). In general, however, as is shown by the history of market development in the West African SATs, the markets for improved inputs and input-related services lag behind those for the products. The introduction of improved crop technologies can be slowed in areas where markets for inputs and services are still relatively poorly developed (Areas 1 and 3). Historically, market-system development, particularly on the input side, has been concentrated where rainfall is high enough for cash crops to be grown (Areas 4 and 6). Recently, however, there has been considerable success with maize and oilseeds in the SATs, these initiatives were cash crops sold domestically to consumers further south but they have now also become a food crop for the producers themselves.

Though the use of oxen to replace human labour is an obvious attraction, the cost affects their potential in the West African savanna. Where new inputs are part of a technology package, their ability to replace other inputs, or to complement them, must be considered. Because oxen or donkeys have not been used in the traditional food production sector in the West African SATs, labour-saving technologies using animal traction have worked better where there is adequate rainfall for cash crops (Areas 4 and 5) rather than where market system development is poor (Areas 1 and 2). They have also worked better when combined with yield-increasing technologies intrinsically more relevant to locations like Area 6.



Source: Norman *et al*. (1982)

Input delivery systems and input-related services are likely to be more relevant where land is a constraint and land is intensively used. Yield-increasing techniques, including the use of the improved seed, fertilisers, and pesticides, make it easier for scientists to develop improved technologies suited to districts like Area 6 than for those like Area 4.

With scientists' current orientation, prospects are not good for developing technologies to benefit farm households in locations such as Areas 1 to 3, where market systems are generally poorly developed. Though it would not increase productivity spectacularly, some progress could be made in such areas by scientists changing their orientation from modifying the environment to fit the plant to modifying the plant to fit the environment.
The greatest challenges lie in Areas 2 and 3 where both marketing systems are poorly developed and the unexploited carrying capacity of the land is small compared with Areas 5 and 6. Although this discussion focuses on the interdependence of support systems (i.e., market-structure development) and improved technologies, there are also interdependencies within villages between the two types of factors.

From the communities' point of view, designing and implementing relevant strategies that help all farm households are desirable. Such strategies should include both improved technologies and support systems.

Heterogeneity within the villages must be recognized when designing such strategies. The challenge is to find ways to help disadvantaged farm households. It is easy to design improved technologies suitable for large-scale farmers only, but it is almost impossible to do so just for small-scale ones. Where support systems are limited or there is a hierarchical village structure that causes problems of accessibility, the probability of differential access is greater than elsewhere. The need here is to design a cost-efficient support system that will ensure fair access but not alienate the village leadership.

The above indicates broadly that the relevant improved technologies chosen will be determined by the interaction of several variables, socio-economic and physical. In contrast to this differentiation, it is important to note that the physical characteristics and constraints that define the SATs provide a degree of commonality to the general approach for developing appropriate technologies. The rainfall patterns and soil heterogeneity pose five important implications:

1. Farmers are likely to adjust their farming plans as the cropping season unfolds. This means that, by using a decision-tree strategy, the area planted, the crops grown, and the practices used can be very different from those originally planned. The implication is obvious: researchers need to mimic such sequential decision-making by developing options from which the farmer can choose, depending on the seasonal circumstances.
2. The heterogeneity of a farmer's soils (and, for that matter, of the resource base) implies the need to target technologies to varied situations to make them more relevant. Such a location-specific approach demands greater emphasis on farmer-based work and farming systems research than is necessary for more uniform, favourable environments.
3. Because of the uncertain and heterogeneous characteristics of the SATs, researchers need to develop considerable amounts of conditional information indicating what should be done 'if this or that happens.
4. Because of the harsh and heterogeneous nature of the SATs, most technologies are likely to give incremental changes rather than marked jumps in productivity. Unlike the more favourable environments of the Green Revolution areas, much more attention needs to be paid in the SATs to the lower rungs on the technology ladder. This is because these often relate to ensuring better timeliness in operations to maximize the return from

limited soil moisture. As a result, they require relatively large changes in the farming systems for their implementation. Such 'lumpy' changes are much less likely to be adopted, without substantial cajoling and support than the 'divisible' types of technology (e.g., improved seed, fertiliser) associated with the Green Revolution. The latter land-intensive technologies only start to become relevant after the 'lumpy' changes have been adopted.

5. Given the environment of the SATs and the precarious level of living of most farmers, it is likely that a high premium will be placed on the stability of return (e.g., a certain level of food grain production each year to meet household needs). Most farming households in the SATs are likely to interpret this in terms of self-sufficiency (producing the food themselves) rather than in terms of food self-security achieved by earning enough to ensure adequate food for the household. In the Indian SATs, variation in supplies may result from annual variations in the area planted because of differences in the number of planting rains, rather than from variations in yield per hectare. Although this kind of factor is recognized, researchers still need to concentrate on technologies that ensure reliable yields per hectare, even though they do not give maximum yields in some years. This may be justified because: (a) farmers often articulate stability of yield as an issue; (b) as population densities increase, the land will become more limiting, so the variation in area planted is likely to decrease; (c) the marked variation in rainfall pattern in some of the harsher parts of the SATs (e.g., Botswana) means that farmers are likely to suffer wide annual variations in area planted and in yields per hectare.

3.8 Ecological sustainability

It is more challenging to attain and maintain ecological sustainability in regions where it is difficult to increase agricultural productivity (e.g., Area 3) than in areas where agriculture has become to some degree commercialized (e.g., Area 6) and where some reliance can be placed on profitable new technologies, market access and external inputs. Even the more favourable areas face problems because:

- appropriate new technologies cannot be devised and introduced fast enough to match ever-increasing population densities, both from local fertility and lowered mortality and from migration from less favoured areas;
- the trend towards free-market economies and reduction of fertiliser subsidies (e.g., more than 80% in Nigeria), credit, etc., which will make external inputs less attractive though perhaps more readily available. One point of concern is that, over the next

20 years or so, increasing scarcity of phosphatic fertiliser and fossil fuels may cause rising prices;

- the continuation of commercially-oriented farming systems is likely to encourage specialization as in some of the maize-growing areas of northern Nigeria where cereal crops are emphasized at the expense of legumes. In India too, increased integration of the economy, aided by improvements in marketing and infrastructure, has resulted in increased specialization in agricultural activities based on comparative advantage.

3.9 Need for a coordinated approach

The separate measures generally used to increase productivity and ecological sustainability have not been particularly successful. For example, the approach to problems of soil erosion by soil conservation specialists has often been expensive and fruitless. A new perspective is needed. Three broad kinds of measures need to be implemented to bring congruence to agricultural productivity and sustainability in an acceptable, resource-efficient way. These are preventive, corrective, and policy measures. The following discussion focuses on the approach to land degradation, but it could equally be applied to other aspects of sustainability.

3.9.1 Preventive measures

These aim to prevent loss of soil productivity by developing and disseminating technologies that yield short-term production benefits and at the same time at least maintain the long-term productivity of the land. This approach involves:

(a) the screening of all potential technologies to ensure, as far as possible, that they will have no negative environmental impact; and

(b) the development of technologies that have a positive production impact and are also likely to enhance soil productivity in the long run. This implies changes in the types of research to be encouraged.

Much greater emphasis is needed on productive legumes, for human and livestock consumption and mulching and green manure. Though there have been increases in rainfed production of oilseeds in India, there has not been a general Green Revolution in legume husbandry.

Increased emphasis needs to be placed on technologies with small external inputs. Good examples would be the development of cultivars that improve the efficiencies of the use of soil nutrients and soil moisture, or cultivars that are striga resistant.

Greater attention needs to be paid to the constructive exploitation of the biological interactions in traditional farming systems. This implies favourable consideration of biodiversity, nutrient recycling, the role of mixed cropping in reducing soil erosion, alley farming, tree legumes, windbreaks, etc.

The exploitation of biological interactions to attain ecological sustainability is critically important where commercialization of agriculture is very limited. It could also have a key role in reducing reliance on external inputs in districts where agriculture is already highly commercialized.

All this implies changes in the approach to research and extension work:

- Research. The conventional reductionist approach to developing improved technologies needs to be complemented by a more complex participatory systems approach. This is necessary because of the required change in direction from a commodity- to a production-systems or farming systems approach.
- Extension work. Greater emphasis is required on information-based technologies rather than on material-input technologies. This change from a commodity to a production system emphasis implies a need for re-organized extension services that interact effectively with farmers or for greater use of farmers as surrogates for extension agents.

3.9.2 Corrective measures

These are mainly physical and have been part of the traditional approach to soil conservation. They emphasize physical structures to check further erosion once it has developed or in some case to avoid erosion on land just being opened up to cultivation. Appropriate solutions need to be based on an understanding of the causes of the soil erosion, rather than on the symptoms.

3.9.3 Policy measures

Preventative and corrective measures are not mutually exclusive; indeed, they overlap. The thrust of overall policy can be used to coordinate the best approach. Policies can be devised that prevent losses in soil productivity or erosion arising in the first place and also help to check them, once they have developed.

This involves designing and implementing policies that:

(a) eliminate possible conflicts between the short-term aims of production and measures designed to encourage long-term sustainability (i.e., conservation);

(b) use incentives to encourage the adoption of strategies that conserve the environment for use by future generations.

The first approach is preferable. Using appropriate technology, is likely to be more effective in maintaining soil fertility and in promoting good land-use management. The second approach, on the other hand, is likely to be more effective in rehabilitation programmes. A combination of strategies is most likely to maximize the effectiveness of a soil conservation programme.

It is critical for success that programmes designed to sustain or improve soil productivity exploit the complementary relationship between technology and policy. For example, policy measures relating to soil conservation can be influential in encouraging or discouraging the adoption of technologies developed as preventative measures. Heavily subsidized chemical inputs, for example, may discourage the adoption of other technologies that rely less on chemicals and have a neutral or positive rather than negative impact on ecological sustainability. Implementation of policies that encourage greater community responsibility and control of natural resources could be used constructively in encouraging sustainability. The increasing individualization of tenure occurring in many areas could also be used in this way.

The policies can be used in two other ways to encourage farmers to adopt strategies encouraging ecological sustainability:

- Subsidies for soil conservation measures may make them more attractive to farm households. They are likely to be most applicable in the promotion of corrective measures which usually emphasize physical structures. They are not likely to be very attractive to farm households close to survival level who do not see degradation or erosion as immediate threats. Soil conservation itself offers little in the way of immediate benefits though it may lead to benefits in the future. Finally, severe limits to government budgets are likely to preclude subsidies to strategies that pay off only at some time in the future.
- Cross-compliance policies can be designed to encourage production and conservation simultaneously. This carrot-and-stick approach fosters the notion that, if something is taken out of the land to encourage production, something then needs to be put in to sustain productivity in the future. It requires that the farmers participate in a specific conservation practice if they are to benefit from programmes designed to stimulate production. In the

USA in recent years, production and conservation policies have been increasingly linked. For example, government-subsidized loans are available to purchase inputs only if the farmer pursues certain conservation strategies. Unfortunately, such policies appear not to be applied currently in low-income countries. Cross-compliance policies may be difficult to put in place for farmers operating near the survival level. On a related point, legislation is often used in high-income countries to control or prevent damaging practices such as the overuse of chemicals causing pollution of water supplies. In low-income countries, however, short-run pre-occupations, such as ensuring enough food for next year predominate. Only limited resources are therefore available for enforcement of any approved legislation and many households are unable to pay penalties for any violations. Thus, it is unlikely legislation will be very effective. Consequently, using market forces as far as possible to encourage sustainability is favoured rather than instituting expensive and unenforceable regulations. This could, for example, involve the elimination of overvalued exchange rates and/or the removal of subsidies on credit for the purchase of fertiliser, pesticides, etc.

The combined objectives of all these strategies should be to bring convergence between the private short-term interests of farm households wishing to achieve an adequate current standard of living and the long-term interests of society in maintaining the environment for future generations. The carrot-and-stick approach is likely to be more practicable than encouraging the adoption of conservation strategies through direct soil conservation subsidies. If possible, the preventative approach is the least costly and most attractive.

3.10 Exogenous and Endogenous factors

Exogenous factors are those largely out of the control of the individual household such as:

(a) community institutions, including structures, norms, and beliefs
(b) support services and policies, related to extension, credit, input distribution systems, markets, and land tenure
(c) Non-institutional factors, such as population density, location and infrastructure development.

Endogenous factors, on the other hand, are those that the household manages to some degree, including land, labour, and capital.

The availability of inputs and the farmers’ managerial ability differ for each household. These differences will affect the performance of its farming system. The household is both a production and a consumption unit. Decisions on agricultural resource management are made this level. For example, sector policies and programmes influence community decisions. These in turn influence household choices. Influences too can work the other way as household decisions can influence sector policies.

The extent to which a farming system fulfils the household goals depends, amongst other things, on managerial skills and, in most semi-arid areas, considerable luck with the weather and other uncertain environmental elements outside household control. The dynamic aspect of farming systems should also be noted: current farming systems reflect the cumulative interaction of the biophysical and socio-economic elements over time.

Below are the endogenous and exogenous factors that influence farming systems of a place.

Endogenous

- Family composition
- Health and nutrition
- Education
- Food preferences
- Risk aversion
- Attitude/goals
- Gender relations

Exogenous

- Population
- Tenure
- Off-farm opportunities
- Social infrastructure
- Credit
- Markets
- Prices
- Technology
- Input supply
- Extension
- Savings opportunities

SELF-ASSESSMENT EXERCISE

Some farmers live at the fringes of the State capitals of Nigeria. Evaluate and assess these farmers concerning:

i. source and cost of capital,
ii. land availability,

iii. labour cost and availability,
iv. government policy on subsidies,
v. marketing.

In your opinion, how sustainable is this farming enterprise?

4.0 CONCLUSION

A farming system is an integrated set of activities that farmers perform in their farms under their resources and circumstances to maximize productivity and net farm income on a sustainable basis. The farming system takes into account the components of soil, water, crops, livestock, labour, capital, energy and other resources including managerial skills. The decision to practice a particular farming system is influenced by these resources, policies and activities. Agricultural development of the semi-arid region of Africa requires, amongst other things, the efficient operation of market forces and the development of productive, more sustainable technologies. Technological 'fixes' to ensure long-term sustainability are unlikely. Even in high-income countries, where the standard of living of most farmers is much better, non-market incentives (subsidies) are still applied in a search for sustainability. Any proposed market and profit-oriented strategies need to be supplemented with natural resource management components that are compatible with long-term sustainability. The carrot-and-stick approach is likely to be more practicable than encouraging the adoption of conservation strategies through direct soil conservation subsidies. If possible, the preventative approach is the least costly and most attractive.

5.0 SUMMARY

A variety of constraints play into farmers' decisions, including constraints concerning available production technologies, biophysical or geophysical constraints, labor and input market constraints, financial and credit constraints, social norms, policy constraints, and constraints to knowledge or skills.

Other important factors affecting farming systems across the globe include education or knowledge on farming, technology, political factors such as government policies, and social factors such as land ownership and inheritance and type of farming in practice.

Farmers need to understand these factors in the given areas they wish to embark on farming to be able to choose the right crop to grow. Choosing the right crop for any given agricultural region is dependent on the type of farming system that is prevalent in the location if the farmer must succeed.

6.0 TUTOR-MARKED ASSIGNMENT (TMA)

1) Mention the physical factors that influence the farming system of a location
2) Explain in detail the climatic factors that affect farming systems
3) How do socio-economic factors influence the farming system of a region?

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MODULE 2

UNIT 1 CHARACTERISTICS OF TROPICAL SMALL SCALE FARMING SYSTEMS

CONTENTS

1.0 INTRODUCTION

Tropical Small-scale agriculture is the type of agriculture that is practiced by small-scale farmers on a fragmented land usually targeted for subsistence purposes. Though on a small scale, this category of farmers are important as they provide the bulk of food and fibre requirements of the nation. Farmers tend to pursue activities that increase their income, reduce their financial and physical risk, reduce labor requirements, and they seem to be comfortable with it. Farming operations throughout the humid tropics are complex, diverse and dynamic. The Humid tropics Program seeks to better understand the status of farming system activities including the roles of natural resource endowment and gender, and to identify robust approaches to their improvement. In this way, a more detailed understanding of farm practices and livelihood strategies allows better-informed priority setting of individual farm enterprises and overall systems performance. These understandings also form the baseline for later improvement of farm productivity and household enterprise, and allow better linkage to rural development plans of national and local institutions.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- identify the characteristics of tropical small scale farming systems
- list the importance of tropical small scale farming systems
- mention the types of tropical small scale farming systems.

3.0 MAIN CONTENT

Tropical regions of the world are predominantly rural, with the majority of the population engaged in agriculture. Majorities of farmers cultivate small, fragmented parcels of land, yet are responsible for the bulk of food production, making the smallholder farm sector a key player in the rural economy. A farming system is explained as the complex of resources that are arranged and managed according to the totality of production and consumption decisions taken by a farm household, including the choice of crops, livestock, and on-farm and off-farm enterprises. Smallholder farming systems are perceived to share certain characteristics which differentiate them from large-scale, profit-driven enterprises. These include:

- Limited access to land
- Low financial capital and inputs
- High levels of vulnerability
- Low market participation.

However, at the macro- and micro-level structures, drivers and constraints of these systems are shaped by constant interaction with the local social and biophysical context. The result is farming system diversity in space (*e.g.* based on resource endowment), variability through time (dynamism) and multidimensionality in terms of strategy (production and consumption decisions). Therefore, not all smallholders are equally land constrained, resource-poor, or market-oriented, and any effort to understand or develop the smallholder sector needs to start with an acknowledgment of this heterogeneity.

1.1 Characteristics of tropical small scale farming systems

- Very small farm size: Farm size is very small in the tropics. The mean farm size is often less than four hectares. Farms are generally smaller in the forest agro-ecological zone than in the savanna. It is relatively easier to clear savanna vegetation than that of the rain forest.
- The predominance of hand labour. Small scale farming is largely dependent on hand labour to about 60-80%. Animal power is

about 20% while use of a tractor is negligible. Tools utilized are usually inexpensive and readily available and the skill required are already there. There is no need for special training unlike in use of machines But it brings about drudgery.

- Predominance of mixed cropping or intercropping. Mixed cropping or intercropping is a widespread cropping practice in the tropics. It is only flooded rice and wheat that are not grown in crop mixture. The advantages include efficient utilization of environmental resources particularly when crops of different maturity cycle complement each other.
- Priority for subsistence food crops. It is characteristic of smallholders to produce first food for home consumption before any consideration for cash crop. A food crop can become cash crop when produced in surplus.
- Small scale farming system can be characterized as a very efficient way of producing crops often surpassing production per land unit when compared to regular large-scale commercial farming.
- Animals (especially larger ones) on small-scale farms are quite uncommon, small farms mostly focus on crop production, often with chickens and sometimes small ruminants.
- Small scale farms often use crop rotation systems making them less vulnerable to pests and diseases

3.2 Importance of tropical small scale farming systems

- Builds up communities: A small-scale farm supplies the local community with fresh food and thus reconnect people with the food they consume. This helps to build up a whole community centered on a small farm, helping out both the farm and the people.
- Improves Health of communities: Introducing more nutritious and sustainable food, helps to improve the overall health of customers. They will not only get high-quality food but often also a higher quantity of locally produced seasonal crops.
- Creates jobs: During the stressful harvest months, small farms often require some outside help in exchange for money or food. Harvesting, selling and maintaining a farm is hard work and so extra labour is required.
- Small farms improve soil quality: In commercial farming, very little thought is given to soil health, but on small farms, the soil is the heart and soul of the whole operation and is therefore treated with respect. Small farms often try to not only maintain the quality of the soil but improve it over time, so that future generations will profit even more from this farming method.

- Food security: Small farms grow a more diverse crop selection. Bigger farms often grow only a single crop on a very large scale. In bad years, when large proportion of farm harvest is lost, the small farms help to counteract the food systems instability in those years.
- Better for the environment: Most of the food produced in large farms will travel more than 1000 miles until it finally reaches the supermarkets' shelves. Furthermore, to produce these large quantities of food within a short period would require a lot of high-tech equipment. Pesticides and oil-based fertilizers also contribute to the negative effect on the environment.
- More productive: Against the widespread belief, small farms are far more productive when compared to larger operations that adopt unconventional farming methods.
- Small farms can offer high-quality food at a good price: Most small farms sell their products directly on the farm. In this way, they do not have to pay for transportation or other fees. You know where your money is going if you choose to buy from a local farm and will be able to see your food being produced.

3.3 Types of small scale farming systems

They are: Nomadic, shifting cultivation, Fallow, Rotation, Permanent cultivation, ley farming, intercropping, mono-cropping, sole cropping, sequential cropping, relay cropping, strip cropping.

Nomadic
This is a type of agricultural farming systems similar to pastoral farming. However, herdsmen move their animals around in search of suitable grazing fields and water. Animals usually moved include; cattle, sheep, goats, camels, horses, and donkeys.

In Africa, there are incidences of nomadic herdsmen leading their cattle into farmlands and destroying them. This has caused various conflicts between the herdsmen and other farmers.

Features of Nomadic farming

- Movement of herds.
- Herdsmen and their herd settle on fresh grazing fields for as long as it lasts.
- In West Africa, encroachment into crops farms and destroying them.

Shifting Cultivation
With this system, the farmer clears a piece of forest land by felling and burning the vegetation residue including the tree trunks and branches.

This piece of land is used to grow crops for three to five years. The farmer abandons this land after it loses its fertility for a fallow period. He moves with his household/community to a new area to cultivate new fertile land. The process is repeated and the farmer may come back to cultivate former lands after it has been left for years to regain its fertility.
The practice is discouraged in modern days due to the scarcity of fertile lands. The government also discourages the practice due to the dangers it poses to forest reserves and nature. It is an unsustainable agricultural practice.

Features of Shifting Cultivation

- Clearing and burning of the trees.
- There is a consistent decline in production levels after a couple of years.
- The land loses its fertility and is left for a fallow period.
- Households/families migrate to a new area for fertile lands.

Fallow System

Fallow system or Bush Fallowing This is a modified form of shifting cultivation. The land is cultivated for some years, when it's nutrients is exhausted, it is then allowed to go back to bush for six to twelve years to regain its fertility before it is used again. The decayed leaves and plant parts help to enrich the soil during the resting period. However, with increase in demand for land for other purposes, the following period is now limited to 2-4 years.

Advantages of Bush Fallowing

i. It is a simple, cheap and effective method of restoring soil fertility.
ii. It helps to control build-up of harmful insects, pests and diseases.
iii. The plant cover helps to check erosion.
iv. Its natural leaves forms humus, thereby increasing soils structure.

Disadvantages of Bush Fallowing

i. It can only be practiced when land is abundant.
ii. The bush which is usually cleared by burning affect some economic trees.
iii. It wastes land.

Crop rotation

Crop rotation is the systematic planting of different crops in a particular order over several years in the same growing space. This process helps maintain nutrients in the soil, reduces soil erosion, and prevents plant diseases and pests.

***Uses*:**

- It helps to control erosion by improving soil stability. Rotating between deep-rooted & shallow-rooted crops each planting season keep the soil stable
- This system allows farmers to increase productivity by reducing or replacing fallow periods.

Permanent cultivation system

A permanent crop is one produced from plants that last for many seasons, rather than being replanted after each harvest. Traditionally, "arable land" included any land suitable for the growing of crops, even if it was being used for the production of permanent crops such as grapes, oranges, mango, etc. Permanent crops are perennial trees like citrus, cashew, cocoa, coffee, etc. It plays an important role in shaping the rural landscape and helping to balance agriculture within the environment.

Ley farming

Ley Farming is also known as rotation pasture. It is a system in which there is a combination with crop production in alternation. This is practiced where the pasture is of such quality, nutritionally and morphologically that will not fit into the crop rotation system.

Intercropping

Intercropping is the cultivation of two or more crops simultaneously in the same field. Intercrops are complementary crops and they do not affect the main crop. In intercrops, short-duration crops are raised with long-duration ones without any reduction in the population of the main crop. The main principle in intercrops is that the introduced crops should have a little competitive effect on the main crop. In the whole analysis, the productivity of the farm is increased.

Mono-cropping

Mono cropping is the agricultural practice of growing a single crop year after year on the same land, in the absence of rotation through other crops, or growing multiple crops on the same land (polyculture). Rice most time is planted year after year on the same piece of land. Mono-cropping allows for farmers to have consistent crops throughout their entire farm. They can plant only the most profitable crop, use the same seed, pest control, machinery, and growing method on their entire farm, which may increase overall farm profitability.

Sole cropping

Growing one crop alone in pure stand, either as a single crop or as a sequence of single crops within the year. It is the opposite of intercropping. "One crop variety is grown alone in pure stands at normal density in a field".

Sequential cropping
Growing two or more crops in a sequence, planting the succeeding crop after the harvesting of the previous one. Sequential cropping refers to growing crops in sequence within a crop year, one crop being sown after the harvest of the other. When two or more crops are grown in a year on the same land, the system is referred to be double-cropping or multiple cropping

For example, Rice followed by pigeon pea, Pigeon pea followed by maize.

Advantages:
- It produces a variety of crops; the legume improves soil fertility.
- Rotation helps reduce pest and weed problems.
- The residues from one strip can be used as soil cover for neighboring strips

Relay cropping
Growing two or more crops in a sequence, planting the succeeding crop after flowering but before the harvesting of the preceding crop. Relay cropping is a method of multiple cropping where one crop is seeded into standing second crop well before harvesting of second crop. Relay cropping may solve several conflicts such as inefficient use of available resources, controversies in sowing time, fertilizer application, and soil degradation.

Relay cropping is a specialized version of double cropping, where the second crop is planted into the first crop before harvest, rather than waiting until after harvest. Relay cropping makes efficient use of available on-farm resources and removes conflicts with sowing time and fertilizer application, and improves soil condition by avoiding preparatory tillage as practiced in conventional agriculture systems.

Strip cropping
Growing two or more crops simultaneously in alternative plots arranged in strips that can be independently cultivated. This is a type of cultivation in which different crops are sown in alternate strips to prevent soil erosion.

In strip cropping, different crops are grown on the same field in different strips or patches, usually alternatively. It is used when a slope is too steep or when there is no alternative method of preventing soil erosion.

SELF-ASSESSMENT EXERCISE

Critically assess the characteristics of small-scale farming in Nigeria and identify areas of possible intervention by the various State governments with a view of improving productivity. Do you think these interventionist approaches will bring enough food to our tables?

4.0 CONCLUSION

Agricultural farming systems are a set of strategies put in place to manage available resources to achieve economic and sustainable agricultural productivity thereby meeting the needs of farm households. The farming systems approach is useful in preserving resources and sustainably maintaining the environment. In an attempt to achieve these noble objectives, series of types of farming systems were embarked upon in line with the prevailing agro-climatical environment and the socio-economic conditions of the people.

5.0 SUMMARY

The farming systems of people are complex and it requires an understanding of the heterogeneity of man and his environment. There are various types of farming systems with particular features and uses sharpened by man and his environment. In our attempt to describe the farming systems of the people we came across terms like shifting cultivation, fallow, rotation, permanent cultivation, ley farming, intercropping, mono-cropping, sole cropping, sequential cropping, relay cropping, strip cropping, and nomadic.

6.0 TUTOR-MARKED ASSIGNMENT (TMA)

1) Given the present population explosion in Africa, is the bush fallow system feasible? Give reasons
2) Differentiate between mono-cropping and sole cropping
3) Under what conditions is stripe cropping necessary?
4) Mention the features of shifting cultivation as a system of farming. In your opinion, is this system sustainable in Nigeria? Give reasons.

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MODULE 3

UNIT 1 IMPORTANT CROP-BASED FARMING SYSTEMS

CONTENTS

1.0 INTRODUCTION

Crop-based farming system is synonymous with cropping system. It refers to the crop production activity of the farm. It describes the entire cropping pattern grown on the farm and their interaction with farm resources, other household enterprises, the physical, biological and socio-economic factors of the environment.

The term cropping system refers to the crops, crop sequences and management techniques used on a particular agricultural field over years. It includes all spatial and temporal aspects of managing an agricultural system. The main focus of agricultural production lies on challenges faced by crop producers in the areas of marketing support, sustainable cultural practices, integrated pest management, environmental and human health risks, regulations, and profitability.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- explain the meaning of cropping system
- identify types of crop-based farming systems
- enumerate the importance of cropping systems
- differentiate between farming system and cropping system

3.0 MAIN CONTENT

A cropping system refers to the type and sequence of crops grown and practices used for growing them. It encompasses all cropping sequences practiced over space and time based on the available technologies of crop production. There are different types of agricultural production system depending on the type of crop and its use. The types of feed or row crop grown by farmers depends on the traditional, organic, or conventional management systems available. Crop production also includes feed sources and resource inputs used to produce crops required to maintain the dairy herd and contribute to the meat industry.

3.1 Crop based farming systems

Crop-based farming system is synonymous with cropping system. It refers to the crop production activity of the farm. It describes the entire cropping pattern grown on the farm and their interaction with farm resources, other household enterprises, the physical, biological and socio-economic factors of the environment. Examples include mono-cropping, strip farming, intercropping, crop rotation, multiple cropping, etc.

3.2 Types of crop-based farming systems

Several hybrid crop production systems are arising due to availability of certain natural resources and other factors. Monoculture, crop rotation, fallow in rotation, multiple cropping, mixed cropping, intercropping are the different cropping systems, which help in maintaining soil conditions and controlling pests and diseases on crop plants. Similar to this is crop production practices which include subsistence farming, mixed farming, plantation farming fallow farming, and shifting cultivation. Cropping systems have been traditionally structured to maximize crop yields.

Examples of types of crop-based farming systems include:

- Fallow systems
- Monoculture
- Strip cropping
- Multiple cropping
- Contour strip cropping
- Crop rotations
- Cover crops
- Mixed and relay cropping
- Organic farming

3.3 Importance of cropping systems

Fundamentally, cropping systems have been traditionally structured to maximize crop yields. Other uses or importance of cropping systems include:

- Good conservation tools that can be used to increase nitrogen use efficiencies
- Reduce nitrate leaching
- Mine nitrates from groundwater
- Improve soil and water quality
- Contribute to atmospheric carbon sequestration.

3.4 Difference between farming system and cropping system

The main differences between farming system and cropping system are as tabulated below.

Cropping system	**Farming system**
The cropping patterns used on a farm and their interaction with farm resources, other farm enterprises and available technology which determines their make-up is called cropping system.	Farming systems represent integration of farm enterprises such as cropping systems, animal husbandry, fisheries, etc., for optimal utilisation of resources leading to remunerative farming.
Includes, mono-cropping, multiple cropping, intercropping etc…	Includes, dairy, piggery, crops etc…
Here there is no recycling of crop residues.	Farming system follows crop residues recycling,
Cropping system mitigates adverse effects of aberrant weather.	Farming system doesn't mitigate adverse effects of aberrant weather.
Examples: rice based cropping system, wheat based cropping system, oilseed based cropping system, and sugarcane based cropping system.	Examples: wet land based farming system; dry land based farming system, garden land farming system.
Some indices are available to evaluate cropping system.	There are no special indices or index not available to evaluate farming system.

Crop based farming systems

Low land rice based

"*Lowland*" indicates a cultivation practice of growing ric*e* under either irrigated or rainfed conditions with impoundment of water to flood the soil—typically during land preparation for rice production and during at least part of the rice-growing season. The soil is largely anaerobic during the periods of flooding

Upland cereal based

One of the most important aspects of formulating a cropping system for an upland situation is the selection of crops and varieties that are suited to the environment in terms of yields and quality, bearing in mind food habits, nutritional requirements and nutrient availability. Most at times, these expectations are rarely met. In the absence of the possibility of increasing the cultivable area, the only way out is to increase productivity per unit area and time. While a cropping system on irrigated uplands can be manipulated in a variety of ways, the crops and the system of cropping on rain-fed uplands afford less flexibility, in so far as they necessarily depend, primarily, on the effective utilization of the precipitation received before and during the cropping season. Climatic and edaphic factors contribute significantly to the success or failure of the harvest.

Root crop-based

The Root Crop Farming System in Nigeria is largely in the moist sub-humid and humid agro-ecological zones. Major crops are maize, cassava, sweet potato, cowpea, sorghum, banana (Musa spp), groundnut, millet and beans. The Root Crop Farming System is found mainly within the Tree Crop and Forest-Based Farming Systems in the south and the Cereal-Root Crop Mixed Farming System on the northern majorly north-central region. Rainfall is either bimodal or nearly continuous and risk of crop failure is low.

Small scale mixed farming

Small scale mixed farming is an agricultural system practiced on the same piece of land by farmers to cultivate crops and raise animals simultaneously. Different crops with different maturity periods are grown continuously throughout the season at same time using best practices with good rainfall or irrigation facilities.

Irrigated smallholder farming

This is irrigation practiced by individual farmers or smallholders, usually farming on a small scale (a few hectares) under their responsibility; usually at low-cost with little or no government support

and using technology they could understand and manage easily themselves.
Irrigation has long been seen as an option to improve and sustain rural livelihoods by increasing crop production. It can reduce dependency on rain-fed agriculture in drought-prone areas and increase cropping intensities in humid and tropical zones by `extending' the wet season and introducing effective means of water control.

Smallholder farming with plantation-perennial
Smallholder farming with Plantation or tree crop farming is an agricultural farming system for farmers of single crop like cocoa, tea, coffee, rubber, oranges, mangoes, etc. grown on a commercial basis on a large piece of land. Annual crops are occasionally planted within these tree crops to keep the farm weed-free and to provide extra incomes to the farmers before the maturation period of the plantation. The system requires good management and technical skills with a substantial amount of capital investment for machines, fertilizers and other facilities.

Crop based and agro-forestry
Crop-based and agro-forestry is a farming system in which trees or shrubs are grown around or among crops. This is a situation where you have an array of forest trees alongside with food crops. These trees sometimes provide the mulch required by the crops or provide the much-needed organic manure for the farm. This intentional combination of agriculture and forest trees has varied benefits, including increased biodiversity, soil enrichment and reduced erosion. Agroforestry practices have been successful in Nigeria and other sub-Saharan Africa countries. due to their benefits.

SELF-ASSESSMENT EXERCISE

Farm crop residues, agro-industrial wastes, farmyard manure, urban wastes, etc are sources of organic matter for our crop use. What are the impediments to the use of organic on our farms despite the advantages of consuming organic-based foods? Is this method of food production sustainable in Nigeria?

4.0 CONCLUSION

Several hybrid crop production systems are arising due to the availability of certain natural resources and other factors. Monoculture, crop rotation, fallow in rotation, multiple cropping, mixed cropping, intercropping are the different cropping systems, which help in maintaining soil conditions and controlling pests and diseases on crop plants

5.0 SUMMARY

Cropping patterns which are also referred to cropping systems become prominent and recognisible in an area based climatic and edaphic factors and their interaction with farm resources, other farm enterprises and available technology which determines their make-up.

Fundamentally, cropping systems have been traditionally structured to maximize crop yields, conserve nutrients and ensure nutrient recycling and sustainably improves soil and water quality. Some of our food crop production practices include mixed, subsistence, plantation farming and others.

6.0 TUTOR-MARKED ASSIGNMENT (TMA)

1) Differentiate between agro-forestry and plantation agriculture
2) Highlight the major differences between farming system and cropping system.
3) Which type of cropping system would you recommend to a community that is surrounded by undulating hills?
4) What are the main determinants for consideration in an upland cereal-based cropping system?

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MODULE 4

UNIT 1 FARMING SYSTEMS RESEARCH: DESCRIPTIVE AND PRESCRIPTIVE

CONTENTS

1.0 INTRODUCTION

A cropping system refers to the type and sequence of crops grown and practices used for growing them. It encompasses all cropping sequences practiced over space and time based on the available technologies of crop production. Cropping systems have been traditionally structured to maximize crop yields.

Now, there is a strong need to design cropping systems that take into consideration the emerging social, economical, and ecological or environmental concerns. Conserving soil and water and maintaining long-term soil productivity depends largely on the management of cropping systems, which influence the magnitude of soil erosion and soil organic matter dynamics. While highly degraded lands may require conversion to non-agricultural systems (e.g., forest, perennial grass) for their restoration. Prudently chosen and properly managed cropping systems can maintain or even improve soil productivity and restore moderately degraded lands by improving soil resilience. Crop diversification is an important option in sustainable agricultural systems which can be further improved upon through adaptive research.

Farming Systems Research (FSR) may be defined as a diagnostic process, providing a collection of methods for researchers to understand farm households and their decision-making. Its applications use this understanding to increase efficiency in the use of human and budgetary resources for agricultural development, including research, extension and policy formulation

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- state the history of agricultural research in Nigeria
- state what is On-Farm-Adaptive Research
- state the steps to follow in the conduct of On-Farm-Adaptive Research
- mention the main constraints to the adoption of recommendations of OFAR by farmers.

3.0 MAIN CONTENT

Although some impressive agricultural research advances had been achieved in some developing countries, there are many areas where research is failing to make a satisfactory contribution to increases in agricultural productivity. Specifically, concerning small-scale farming in developing countries, the insufficient taking into account of real activities (production conditions, practices and strategies) of the local farmers appears to be one of the main factors confronting the success of agricultural research. Many “improved technologies”, although technically sound, are not relevant to the objectives, socio-economic circumstances or even to the agri-climatic conditions of small-scale holders. The increase in food production and food security through the improvement of productivity on both large and small-scale farmers is no longer the only issue that agricultural research and extension should look at. The competitiveness and quality of agricultural products, labour employment, income generation, equity, gender awareness, environmental concerns and management of natural resources also need to be taken into consideration. Farmer participation in research is key in this perspective.

3.1 Historical perspective of agricultural research in Nigeria

Agricultural research in Nigeria started more than 100years ago with the establishment of a botanical garden in Lagos during the late 19th century. By 1903, the Forestry and Botanical Department (renamed Agricultural Department) for Southern Nigeria was created. By 1912, the latter was divided into Northern and Southern regions. By 1914, the Forestry and Veterinary Departments were created.

Research on the economics of agriculture in Nigeria pursued by Nigerians and outsiders alike has concentrated almost exclusively on the need for increased physical inputs and maintenance of private incentives without reference to the structure of production relations among various classes of farmers. There are two important aspects of the narrow and economist views reflected in most of the traditional research. Firstly, it is premised on the false assumption that in agriculture there are linear relations between inputs and outputs and ignores completely the highly differentiated structure of ownership and control of land, the most important earning asset, secondly, this view has been shared almost without change by influential researchers and policymakers alike during the last 30years and what is more, it is still held uncritically despite a large body of dissenting literature even in the west on orthodox economic theory at least about the process of economic development, that researchers in Nigeria remain dependent on foreign expertise even in identifying research needs to sustain agricultural development, is another sad aspect of the state of research in the country. It is now generally agreed that the process of economic development is not simply a problem of resource allocation as the neoclassical theory assumes and is accepted in Nigeria without reference to the objective relations among various groups in the countryside. Like their counterpart in many other developing countries, researchers and policymakers in Nigeria have recently embraced the rhetoric of growth with distribution; they have shown little interest in examining the structure of agrarian relations and their consequences on agricultural development and rural well-being, An alternative approach to research in identifying the causes of slow and uneven growth of agriculture in Nigeria rests on two central questions. First, who owns and controls the land? And how are the production relations organised?

Secondly, how do the different farming regimes affect the use of society's resources and the distribution of the fruits of production?

These questions are intimately related to the issues of access to income-earning assets and participation in the process of development. To understand the nature and persistence of rural poverty, we must start asking the right questions. This paper argues that the immediate need of Nigeria is to make available to farmers large quantities of those low-priced inputs that can bring about large increases in crop production about the cost incurred. In simpler terms, how can economists and other crop and social scientists provide policy guidance within the framework of the current land tenure distribution rather than expanding their energies seeking futile policies to fight it and in the process neglecting policy issues relevant to Nigeria's short-term opportunities for agricultural growth?

Finally, emphasis on technocratic research suited to the requirements of large landowners implies that small farmers (owners and sharecroppers) should be marginalised and alternative employment for the rural poor should be found, this view is as cynical as it is false. Below is the historical evolution of agricultural research in Nigeria, trends, focus, and new frontiers in our research drive.

3.1.1 Historical Evolution of Nigeria's Agricultural Research System

The first research Institutes in Nigeria's national system were created largely to the needs of export crops. The National Cereals Research Institute owes its origin to the erroneous belief of the British Empire Cotton Growing Corporation in 1905 that is Ibadan, in a rain forest was a suitable location for cotton research. After few years of unsuccessful trails cotton research moved to North eventually settling in Samaru, Zaria in the Savannah Zone. The Institute of Agricultural Research (IAR) dates back to 1922 when a Regional Research station was established at Samaru as Headquarters of the Department of Agriculture of the Northern Provinces. Over the years, it has done most of the research on cotton and groundnuts (traditional export crops). In addition, food crops, the Nigerian Institute for Oil Palm Research (NIFOR) had its origins in the establishment of Oil Palm Research Station in 1939. This was replaced by the West African Institute for Oil Palm Research (WAIFOR) in 1951and by NIFOR in 1962. The Rubber Research Institute of Nigeria (RIN) was established for research on rubber a major export. Second were the Pan-Territorial Research Institutes meant for research on export commodities of broad agro-ecological regions in Anglophone West Africa. The West African Research Organisations, the umbrella organisations for these Institutes were dismantled in 1962 in the wake of the nationalist emporia that accompanied independence. This gives rise to the establishment of such National Institutes as Nigerian Institute for trypanomiasis Research (NITR), Nigerian Stored Research Institute (NSPRI) Cocoa Research Institute (CRIN), Nigerian Institute for Oil Palm Research (NIFOR).

3.1.2 Nigerian Council for Science and Technology and its Research Council

In February 1970, a major milestone was reached in the organisation of science in Nigeria with the establishment of the Nigerian Council for Science and Technology (NCST) by the then Federal Military Government. Its main responsibility includes the establishment of priorities of Nigeria and her International commitments, advising the Federal Military Government on National Science Policy, planning for science and Technology, Financial allocation utilisation of results of scientific activities in the development of agriculture and industry and improvement of social welfare. The NCST was also responsible for ensuring cooperation and coordination among various agencies involved in the formulation and execution of science policy and promotion of public confidence in the expenditure on science and its benefits and also promotion of a favourable climate for scientific activities. At this time, the Federal Government requested various Ministries to submit proposals for establishment of research council for agricultural medicine, industry and natural sciences. But while these were under preparation, the Ministries were reluctant to relinquish their control over the respective research Institutes under them and by mid-1970s, there were 20 Research Institutes and 4 Research Councils (Agric Research Council of Nigeria, ARCN, Industrial Research Council of Nigeria (IRCN), Medical Research Council of Nigeria (MRCN) and the National Sciences Research Council of Nigeria (NSRN). Although the

ARCN was established in 1971, the 18 Agricultural Research Institutes established at different times could not come under the aegis of the ARCN until the end of 1976. The IRCN and MRCN similarly took over their respective Institutes in late 1976 and all Councils Institutes were finally transferred to the NCST which assumed budgetary control over all Institutes by the end of 1976. The NCST thus entrusted for about 6years without performing its statutory functions of coordination of Research Institutes. The Council was located in the cabinet office but had no representation in the Supreme Military Council.

During this period, the first National Agricultural Development Seminar was held from July 26 – August 5th 1971 based on this seminar, Agricultural Development in Nigeria 1973 – 1985 (FMANR/JPC 1974) was published and it covers guidelines and policies for Agricultural Research and Development for over a decade. 2.2 National Science and Technology Development Agency (1977–1979) Before the NCST could settle down to function normally and effectively and at the various Councils (ARCN, IRCN and NSPRCN) were abolished by the Federal Military Government and the National Science and Technology Development Agency was established in January 1972. It was headed by an Executive Secretary and had its Chairman, the Chief of Staff Supreme Headquarters who was a member of the Federal Executive Council. The functions of the NSTDA which included formulation of overall science policy and coordination of research in the nation. During 1977, three more Institutes were brought under the aegis of the NSTDA; these Institutes were the Project Development Agency (PRODA) at Enugu, the Nigerian Stored Products Research Institute (NSPRI) and the Agricultural Extension Research Liaison Services at Ahmadu Bello University (ABU), Samaru Zaria. The last of these is not functionally a Research Institutes since it deals with Agricultural Extension but in its semi-autonomous status, it had the same status as any Research Institute in the country.

3.1.3 Agrarian Structure and Land Tenure System in Nigeria

In an agrarian society, such as Nigeria Land is the greatest asset and it forms the basis of all human activities. It is also unique as a gift of nature under the Nigerian customary land tenure arrangements, no land exist without an owner, supervisor or absolute interest are vested in land owners who in Nigeria may be individuals, supernatural persons, corporate bodies and State, etc. Individuals under membership of a family or clan become entitled to portions of family land and enjoy rights of occupancy and use over land, the family constitutes the basic unit of landholding in rural Nigeria while the fundamental basis of land tenure in Nigeria is urban areas has been family house under the traditional or customary tenure arrangements an individual seeking land approaches the head of land. Early in this century for instance, the position was that the family head would inform other family members if there was no objection the individual seeking land would pay a small sum in addition to providing kola nuts.

Agriculturally, an individual enjoys absolute rights of ownership if he is the first to clear the land consequently the individual may lease mortgage or sell property rights of such land to other parties. Supernatural persons comprise of cults, oracles and secret societies with which ownership of certain land is associated in Nigeria. Corporate bodies own land either as corporate or commercial ownerships system known as Corporation aggregate they represent various socio-political groups found in Nigeria where land is abundant and population density is low, the rule of land tenure may not always be strictly enforced under these situations rigid demarcation of land between individual and groups is rare. An individual may farm anywhere within the area of his community continually clearing fresh bush and not claiming any rights over abundant farmland. However, with the growing population density increasing urbanisation and rapid transaction in landed property, permanent right became established in land under the situation once a man has farm a piece of land he usually returns it after the fallow period, he can lose his right to return it only if he exceeded the specified number of years that is the fallow period.
Land tenure becomes a changing institution in response to the needs of man in the society. These changes become manifested in the evolving patterns of land use within the population overtime by the same token a reciprocal relationship is established between land tenure and land use while a dynamic interaction is created in the interplay of factors which influence the behaviour of man to the land.

3.1.4 Funding, Budgeting and Financial Management of Research Institutes

Funding of Research Institutes in Nigeria has often been inadequate, erratic and unpredictable. The amount of funds made available to Research Institutes often bears no relation to the importance of agriculture or its sub-sectors in the economy. In some years to come, funds made available to Research Institutes is often less than the amount approved in the budget and barely enough to cover staff salaries and other prerequisites. A reliable index for budgeting allocations to Research Institutes should be determined and strictly adhered to. Nigeria spends less than 1% of its GDP on research as compared to 2.5% in most developed countries of the world. At present only the Federal Government provides financial research support. This should be reviewed and consideration given to State business and other bodies financing research. Release of funds to Research Institutes should be done early in the financial year or proportionately during the year at specified intervals. Budgeting and financial management at the Research Institute level leaves much to be desired. Budgeting is not used as an effective planning instrument to ensure allocation of the limited funds to priorities. Most Directors keep a very tight run on the budget thus denying various Budget Officers Director's Research, Programme leaders etc the right to exercise their leadership roles in budget control.

3.1.5 Planning and Project Formulation

In most Research Institutes, there seems to be a tendency to initiate research projects in almost all activities covered by the decree establishing the Institute. There is attempt to ensure that priorities are established about national objectives and the needs of farmers and consumers. Moreover, effort is not made to study and understand the farmers physical, biological and socio-economic environment to enhance determining the constraints to increased production and formulating the strategies for solution of problems, the strategies should also be based on manpower and other resources available to technologies that may enhance breakthroughs or successes in funding effective solutions (FMARD, 1981). Elements of technological forecasting should be used in the project design to guarantee that any procedure to be used is within the realm of existing knowledge. Technology assessment may also be necessary in considering the range of alternatives available, their advantages and disadvantages and the probable social and other repercussions of their adoption in the foreseeable future. The current explosion of knowledge and the complexity of agricultural production and especially the multi-disciplinary nature of the agricultural development process calls for a holistic approach in funding solutions to constraints to increased agricultural production. This necessitates a system approach based on interdisciplinary research teams. Since most Scientists are disciplinary trained and oriented in research, special effort should be made in the organisation, planning and management of research teams This is a task that merits the special attention of Directors, Heads of Departments and Programme Leaders. A system approach in research usually requires upstream research activities in study and understanding of the farmers' environment, identifying problems and establishing priorities for on-station research to find effective solutions or technologies and downstream research activities aimed at on-farm trials to determine the extent to which the technology can provide effective solutions. To the farmers' problems and study of problems of adoption and obtaining necessary feedback for improvement of technology as may be necessary. It is not uncommon to find Scientists in our Research stations who in the last ten years have never once visited a farmer's field and have come closest to the farmer when travelling at high speed on the expressway. It should also be noted that adoption of new technology should be associated with monitoring of its effects and changes in existing farming systems and the farmer's environment. The system approach in research is much more necessary in food crops production than in plantation crops which may be researched in single commodity Research Institutes.

3.1.6 Technology Transfer

There is still a wide gap between experiment station yields and those attainable on farmers' fields. Technologies developed in many of our Research Institutes are few and even those claimed to be developed are not readily adopted for various reasons. They may not be relevant to the farmers needs or are not economically viable, they may be beyond his means to own, manage and repair and may not have been adequately evaluated and demonstrated for the users so that the farmers can understand how the technologies function and their potentialities. There are also problems of technology transfer resulting from Institutes not realising that they have a vital role to play in enhancing adoption of new technology not only in selling the technology to the users but also ensuring that there is a mechanism for producing adequate numbers of the materials or for commercial production of equipment at minimum risk. For example, a lot of appropriate technologies and mechanical equipment for small farmers have been developed and evaluated but there are no facilities for their fabrication to ensure that sufficient numbers are available. Sometimes Research Institutes became deeply engrossed in promotional and improved seed multiplication programme to an extent detrimental to their research programme. It would be best to them to assist governments or private agencies to undertake these in different states or ecological zones. Some technologies that have been developed have been subjected to limited evaluation in different ecological zones and the package of production practices in which they can be utilised effectively have not been determined. For example, it is not just enough to produce a new rice variety but also it is also necessary to determine its area of adaptation in Nigeria and the package of inputs necessary for the farmer to realise maximum returns in growing it. Some Research Institute undertakes commercialisation of technologies they have developed to the detriment of their research training activities. It has been recommended that this should only be carried out through establishment of semi-autonomous profit making companies the operation of which should not have adverse effects on the research at the Institute.

3.1.7 Improvement in Research Management

It has been observed that there is as yet no well-established scientific tradition in Nigeria. In the Research Institute system also constant changes in staff, lack of funds, poor facilities and diversity of backgrounds in training and outlook of scientists in leadership positions has resulted in ups and downs in the history of each Institute. These have adversely affected the continuity of improved research management initiatives that may have been introduced at one stage or another in various Institutes. It has been suggested that special research management training visits and sabbaticals in relevant Institutes of excellence in developed countries or relevant ecological zones may contribute effectively to ensuring that they are available in Nigeria Research Management capabilities required for rectifying current deficiencies in the research system.

On the other hand, it can also be argued that each Director or Assistant Director in any Research Institute is treading a unique and narrow path through which few or no Nigerians have trod successfully. Consequently, no training course is likely to provide definite answers and initiatives for improvements in research management in Nigeria. If this is the case, there is a lot that can be accomplished through individual or personal efforts to improve the situations in which leaders in research fund themselves. Directors direct their deputies, Programme and Project Leaders can also benefit a lot from current literature in management generally and more specifically on new concepts and experiences of scientists in research management positions all over the world. It is a common practice for budgetary provisions to be made for purchase of technical books in various disciplines and departments of Research Institutes and Universities. Through such provisions, Scientists can keep abreast of the developments in their disciplines. Similarly, Scientists in leadership positions should take advantage of the current explosion in knowledge and publications in keeping up to date with developments in various aspects of management not only through books which are soon out of date, but also through articles in various journals and periodicals. There are now articles on almost every aspect of human experience in science, technology research and development. Advantages may also be taken of special conferences, seminars and workshops. Such exposure to new ideas and experiences provide good intellectual, philosophical and psychological stimulations for generating personal initiatives which may trigger innovations in research management. It is only through such personal initiatives that individuals can demonstrate that they have the knack for funding unique solutions to specific or local problems. Directors and others in leadership position in science and technology should not regard themselves and having reached the peak of their careers where further improvements is no longer possible or necessary. After all if the Scientist who is a Director of an Institute may have reached the height of incompetence and can only perform better by somehow improving himself or herself through personal continuing education and exposure to new knowledge relevant disciplines and activities a process which is not only achieved by going back to school. A reference to current content and similar abstracting periodicals reveals the scopes of essential literature are in research management and similar problems. Directors and Programme Leaders should take advantage of all existing opportunities to keep up to date with developments in the field of research management and related activities.

This enhances their having the courage and through sequential evaluation of the progress and problems in the Research Institute, insights and initiative to adopt measures to improve morale, service conditions, facilities etc which affect the overall motivation and productivity of research workers under them.

3.1.8 Key Issues in Nigerian Agricultural Research Policy

The inability of the National Agricultural Research system to spearhead the structural transformation of the Nigerian Agricultural Economy suggests a need to identify the critical issues involved in developing an effective system. A clear statement of agricultural research policy objectives is required to rationalise research resource allocations and to ensure consisting with the objectives of the agricultural sector, the macro-economy and society's goals values and aspirations as well as nations factor endowments within the African context such objectives include: -

(i) Creation of new knowledge and technologies in the form of new production and consumption processes, new inputs and new outputs.
(ii) Substituting abundant and cheap resources for scarce and expensive inputs.
(iii) Reducing food and agricultural production costs.
(iv) Raising farmers' incomes.
(v) Making the agricultural sector more responsive to price and other policy incentives by increasing its dependence on productive inputs that are more supply price elastic.

Some or all of these objectives could be translated into quantitative targets in a national plan for agricultural research. Policy objectives have been articulated largely by bureaucrats with farmers and farmers' organisation playing no role. Policy instruments were identified and utilised by bureaucrats with little or no consultation with farmers and farmers organisations

3.1.9 Integration of Research, Extension and Training

The historical circumstances of the evolution of Nigeria's agricultural research system have almost guaranteed the lack of integration of research extensions and training. Initially, there were the Departments of Agriculture for the Northern and Southern Provinces. The Federal Constitution (1954) and Regionalisation of Agriculture gave birth to three Regional Departments and their relevant research arms in addition to the Research Institutes created by the Research Institutes Act of 1964. Since agriculture became a Regional responsibility and by implication extension, the Federal Government was left with an impressive list of Research Institutes but was constitutionally barred from any agricultural extension activities.

By 1975, the Federal Government had taken over all Agricultural Research Institutes but no provisions were made for liaison with State extension services. The system was left with the worst of both worlds. It had neither then unique features of a Rothamsted Experiment Station nor the Integrated System of the US Land Grant College. While the Morrill Land Grant College Act (1862) and the Hatch Experiment Station Act (1887) provided the basis for America's decentralised Cooperative Federal state Agricultural Research System (Peterson and Fitzharris, 1977).

Nigeria's Agricultural Research Institute Decree (1973) and National Science and Technology Development Agency Decree (1977) guaranteed that Nigeria would have one monolithic Federal Agricultural Research system that remains unviable and unworkable in a heterogeneous Federal set up with one or two exceptions, Nigeria's Agricultural Research Institutions remain in total isolation from the Universities, a great contrast to the United States system in which the agricultural experiment station attached to the College conducted research 4.2 An Overview of Economic Research in Agriculture We shall briefly review the nature of economic research on Nigerian agriculture during the last thirty-five years. Generally, two factors play a central role in determining the nature and quality of research in a country. First social and economic research is guided mainly by the dominant ideology and follows a paradigm which this ideology allows to be articulated. Secondly, it is affected by the human and technical infrastructure which a society develops overtime. In this review, it will become clear that a particular ideology has dominated the research process in Nigeria and in this process the country has not become evidently self-reliant even in identifying its research need for sustained agricultural growth The issue of growth with distribution did not by and large catch the fancy of most researchers on Nigerian Agriculture.

Although there was a debate on the issue in Western Nigeria during the era of Green Revolution, most of the research efforts were still being expanded on the technocratic aspect of the process of adoption of new seeds of wheat and rice particularly in Northern Nigeria. There were two important aspects of research on the Green Revolution:

a) They focused on the impact of new technology on agricultural production and incomes without taking into account differences in participation by various farm groups. The only structural dimension they incorporated was farm size.
b) Secondly these studies contained quantitative analysis of resource allocation and productivity at the farm level in contrast with earlier studies which were highly aggregate and used simpler techniques.

3.1.10 Emphasis on Small Scale Farmers

The discussion on the above sections clearly suggests that agriculture needs radical reorientation. This suggestion here is not that all traditional research should be abandoned. However, since Nigeria has a highly differentiated agrarian structure, the narrow and largely technocratic approach ignores the asymmetry of relations among various farm groups.
The technocratic approach is promised on a historical dialectical process. It must be stressed that the differentiated agrarian structure manifest in the asymmetrical relations among the classes on land is itself a barrier to the rapid expansion of agriculture and rural development efforts through either country wide or specific area projects to persuade farmers to adopt modern inputs and grow new crops tend to exclude a large number of peasants in Nigeria.In many development projects established assumedly to involve a majority of farmers, the target groups are not major beneficiaries.

On the contrary, they become the victims of the consequent development. Their numbers grow as marginalised small owners displaced tenant or share-croppers and wage workers. Two crucial areas of research have been ignored by researchers and policy makers in Nigeria.

The first relates to the analysis of the complex inter relations among the various and contending farm groups and their impact on agricultural production and income distribution. Here we should also include in this area a systematic study of wage labourers in agriculture with these questions

- Who are these workers?

- By what process are they being created as a relatively new growing class?
- How are their wages determined?
- How do they compare with landless tenants and marginal owners?

Our knowledge of rural labour, its working conditions and wages and the working of rural labour markets in Nigeria is pitifully meagre. The second area covers the measurement and interpretation of participation by these groups in production related activities in both the private and public sectors for full illustration where four district groups can be identified.

(i) Capitalist farmers using machines and hired labour.
(ii) Small land owners who may be owner operators or part-tenants producing mainly for subsistence.
(iii) Share croppers working on other land in small persels and sharing
output in kind or cash
(iv) Wage labours who are hired on temporary or permanent basis and receives their wage in kind or cash.

It is also necessary to clearly identify the relevant production relations among these groups and activities (be they in the private or in public sector) in which differentiated participation is clearly observed. Some obvious activities are:

- Purchase of physical inputs (seeds, fertiliser and pesticides).
- Purchase or access to irrigation water (Canal and tubewell).
- Purchase of or access to farm machinery.
- Access to farm credits its terms and collateral requirement.
- Access to agricultural extension Services including contacts with Extension Agents and acquisition of physical inputs through them
- Access to markets for crop output, including measure of surplus transportation, dealers and terms of disposal of surplus.
- Existence of and access to cooperative organisation.
- Employment of wage labour including wages and terms.

Research in these areas has a direct bearing on policies about participation by the target groups in agricultural development.

3.2 New Structure Of Agricultural Research In Nigeria 2009 And Beyond

In 1992, the need to realign Agricultural Research to the Federal Ministry of Agriculture was accepted by the Government and Agricultural Sciences Department along with fifteen (15) Agricultural

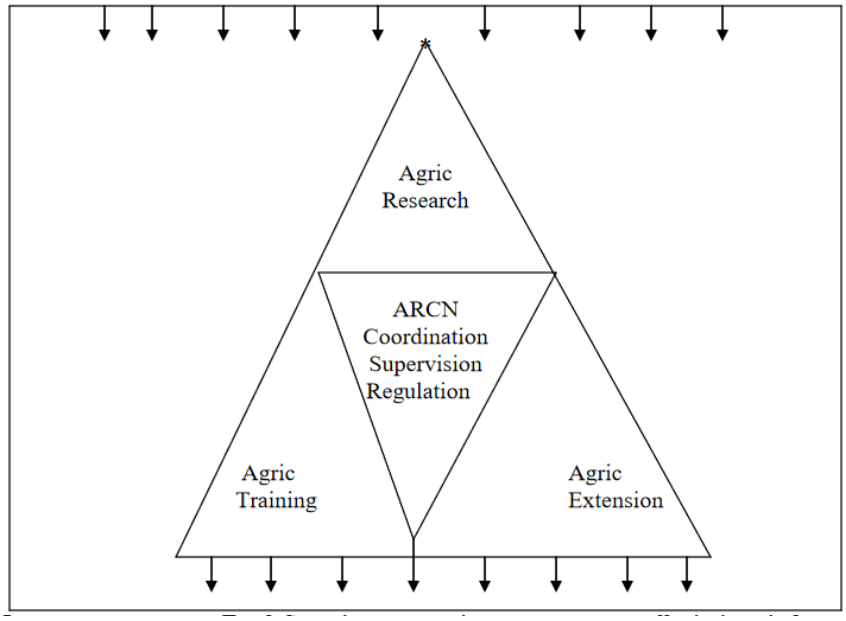
Research Institutes that were formally returned to be fully integrated into their sector. Presently, Nigeria has the largest and most elaborate National Agricultural System (NARS) in Sub-Saharan Africa (SSA). It consists of: -

- 18 National Agricultural Research Institutes
- 3 Federal Colleges of Agriculture
- 47 Faculties of Agriculture
- 8 Faculties of Veterinary Medicine
- 4 International Agricultural Research Centres present in Nigeria
- Several OPS, NGOs, CBOs, FBOs etc.

3.2.1 New National Agricultural Research Service in Nigeria (NARS)

Inputs of MDG national goals, Agric Policy, Research Policy, Farmers, Industry Need/Demands, and National Funds.

Fig.1The New NARS



Outcome → **Food Security, export incomes, poverty alleviation, industry growth, natural resource conservation**.

Source: Anka (2014)

The Agricultural Research Council of Nigeria (ARCN) was established by Decree 44 of 1999 now an Act of the National Assembly. The Decree was published as Extraordinary Government Notice No. 78 of 26th May 1999, Vol. 86.

The ARCN has the mandate for coordination supervision and regulation of agricultural research training and extension in the National Agricultural Research Institutes (NARIs) and Federal Colleges of Agriculture.

ARCN – Is a Corporate body with perpetual succession established as Grade (A) Parastatal of the Federal Ministry of Agricultural and Rural Development. It has a governing board answerable to the Minister of Agriculture and Rural Development. It has a Chairman, members from public and private sectors covering key stakeholder groups. The Executive Secretary is the CEO with four Directorates.

Vision

– The vision of ARCN is to reduce poverty and increase food security by contributing to the establishment of sustainable agricultural growth and development in Nigeria.

Mission

– The mission of ARCN is to achieve significant improvement in agricultural productivity, marketing competitiveness by generating appropriate technologies and policy options, promoting innovation, establishing a knowledge management capacity and strengthening the agricultural research system.

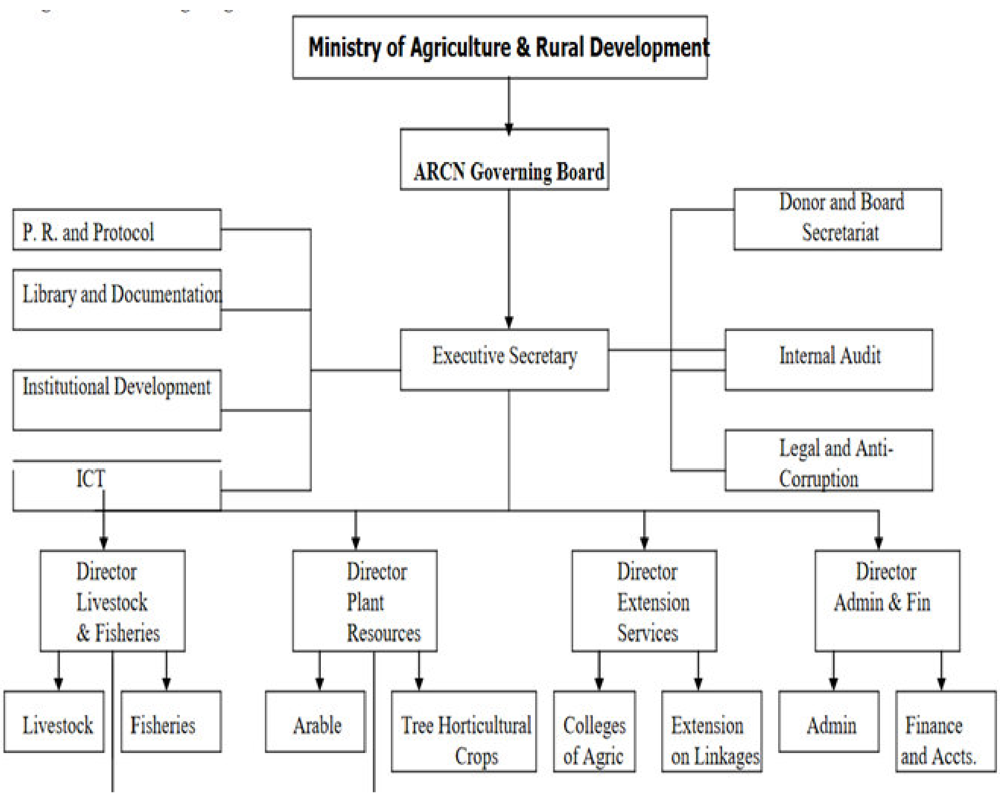


Fig.2 ARCN Organogram

Animal Genetic resources and Plant Genetic Resources are respectively under Director, Livestock & Fisheries and Director, Plant Resources

Source: Anka (2014)

3.2.2 Current Status of Agricultural Research in Nigeria

The fundamental condition for the overall growth in socio-economic development of the developing countries lies in a dynamic agricultural sector which is possible through steady increase in the agricultural productivity. Unfortunately, over the years in Nigeria, the performance of this sector has been on decline. Despite the enormous and diverse natural and agricultural resources as well as an elaborate research system, the sector has significantly underperformed its potentials. Nigeria has continued to import large quantities of rice, wheat, sugar, etc. yield of many crops has remained low as well as productivity of livestock.

The research system was characterised by:

- Lack of linkages, interactions, learning mechanisms among the actors.
- Non-inclusion of farmers' innovations in knowledge system.
- Weak participation of NGOs in research and extension.
- Inadequate, inconsistent and unreliable funding from government.
- Lack of stable coordinating agency and effective mechanism for collaboration.
- Inability of National Agricultural Research Institute to effectively focus limited resources on priority issues.
- Poor state of infrastructure and research facilities.
- Poor staffing situation and absence of functional manpower development programme.

3.2.3 New Research Priorities and Expectation from Research Institutions

Apart from the traditional goals of agricultural research with liberalisation and globalization Research and Development system are confronting new priorities especially:

- Competitiveness of agriculture in local and international market, through technologies that reduce drudgery
- Production costs improve product quality and food safety
- Promotion of higher value added products.

- Conservation of natural resources and the environment through sustainable land and water management
- Reduced agricultural pollution and provision of environmental services through carbon farming
- Conservation of biodiversity.
- Knowledge – intensive agriculture to use existing inputs more efficiently and sustainably Poverty reduction by focusing on commodities, region and technologies to maximise benefits to poor producers and consumers.
- Devising new means of extending technologies generated to farmers.

3.2.4 Expectations from Research Institutions

To be effective and sustainable Research Institutions are being asked to be more responsive and accountable to clients. The challenge now is to effectively involve clients of the research system to generate more responsive, demand-driven impact-oriented research agenda.

3.2.5 New Funding Mechanism

Many of the problems facing agricultural Research in Nigeria relate to funding. The Federal Government for years has been the sole source of funds of National Agricultural Research Institutions (NARI). Funding has not been timely and adequately. In recognition of the role of research, the Federal Government has increased in recent years the level of funding to NARIs by over 500%. The sum of six billion naira has been approved by the government for competitive agricultural research grant scheme. Despite all these, there is the need to put in place other alternative and sustainable funding mechanisms like endowment funds for agricultural research.

3.2.6 Recommended Areas Identified for Focused Research

1) Land and Water Resources

- Use of geographical information system (GIS) and remote sensing for assessment and mapping of soil fertility, soil ailments and general soil survey
- Soil conservation for rainfed agriculture. - Control of land degradation, desertification, salinity waterlogging and nutrient depletion.

2) Field Crops

- Development of hybrids.
- Use of GIS and remote sensing for forecasting of biomass and crop yield.

- Post harvest handling of cereals

3) Horticultural Crops

- Organic farming for exportable commodities
- Development of dwarf rootstocks for high-density planting.
- Breeding for high-yielding varieties HYV of fruits and vegetables especially hybrid.
- Post-harvest management of fruits, vegetables and flowers to meet standards and WTO requirements.

4) Plant Protection

- Epidemiological studies of plant viral and other diseases. Use of GIS and remote sensing in disease forecasting and surveys.
- Establishment of National Pests Risks Analyses Network.
- Establishment of Network of Grain Quality Laboratories/accredited. Post-Harvest Technologies and Quality Assurance
- Research on methods to extend life desired quality in exportable horticultural crops to meet standards (grading packaging material).
- Research on reducing post-harvest losses of major field crops, fruits, and vegetables (storage and transportation techniques).

5) Global Climate Change

- Effect of global climate change on crop yields.
- Effect of global climate change on forests and rangelands.
- Development of agricultural meteorology laboratories network for data base forecasting, modelling and simulation of the effects of changing climate.

6) Livestock and Fisheries

- Genetic improvement of ruminant and non-ruminants.
- Embryo transfer technology
- Production of livestock for export products
- Fertility improvement in cows and buffaloes.
- Research to improve production efficiency of fish farming/inland fisheries.

7) Agricultural Social sciences

- Export-oriented marketing research and development
- Farming system research on economies of alternate cropping systems.
- Strategies to bridge the existing yield gaps for various crops in the country.

Table1: List of Agricultural Research Institutes in Nigeria

S/N	Name Of Institute	Location	Year Est	Mandate
1	Institute for Agricultural Research (IAR) .	P.M.B 1044 Ahmadu Bello University. Samaru Zaria	1924	Genetic improvement and development of production and utilization technologies for sorghum, maize, cowpea, groundnut, Cotton, sunflower, and the improvement of the productivity of the entire crop-based farming system in the North West Zone of Nigeria.
2	Institute of Agricultural Research and Training (IAR&T)	P.M.B 5029, Ibadan, Nigeria.	1956	Soil and water management research, genetic improvement of kenaf and jute, and improvement of the productivity of the entire farming system of the South West Zone.
3	National Cereal Research Institute (NCRI)	P.M.B 8 Badeggi, Bida, Niger State.	1975	Genetic improvement and production of rice, soybean, benniseed, sugarcane and improvement of productivity of entire farming system of the Central Zone.
4	National Root Crop Research Institute (NRCRI)	P.M.B 7006, Umudike, Umuahia, Abia State.	1976	Genetic improvement of cassava, yam, cocoyam, Irish potato, sweet potato, and ginger and overall research in improvement of farming system of the South East Zone.
5	National Horticultural Research Institute (NIHORT)	P.M.B 5432 Idi-Ishin, Ibadan, Oyo State.	1975	Research into genetic improvement, production, processing and utilization of fruits and vegetables, as well as ornamental plants.
6	Nigerian Stored Product Research Institute (NSPRI)	P.M.B 1489 km 3, Asa Dam Road, Ilorin Kwara State.	1977	Research into improvement of major food and industrial crops and studies on stored product pest and diseases, pesticides formulation and residue analysis.
7	Rubber Research Institute of Nigeria (RRIN) .	P.M.B 1049, Iyanomo Benin City, Edo State	1961	Research into genetic improvement, production and processing of rubber and other lather producing plants.
8	Cocoa Research	P.M.B 5244	1964	Genetic improvement,

	Institute of Nigeria (CRIN)	Idi-Ayunre, Ibadan, Oyo State.		production and local utilization research on cocoa, cashew, kola, coffee and tea.
9	Nigerian Institute for Oil Palm Research (NIFOR)	P.M.B 1030 Benin City, Edo State.	1939	Research into genetic improvement , production and processing of oil, coconut, date, raphia and ornamental palms.
10	National Animal Production Research Institute(NAPRI)	P.M.B 1096 Shika, Zaria, Kaduna State.	1977	Research on food animal species and forages.
11	National Veterinary Research Institute (NVRI)	P.M.B 01 Vom, Plateau State, Nigeria.	1924	Research into all aspects of animal diseases, their treatment and control, as well as development and production of animal vaccines and sera.
12	National Institute for Freshwater Fisheries Research (NIFFR)	P.M.B 6006 New Bussa, Niger State.	1968	Research into all freshwater fisheries, and long term effects of man-made lakes on ecology and environment throughout the country.
13	Nigerian Institute for Oceanography and Marine Research (NIOMR).	P.M.B 12729, Victoria Island, Lagos.	1975	Research into the resources and physical characteristics of Nigerian territorial waters and the high seas beyond; genetic improvement, production and processing of brackish water and marine fisheries.
14	National Root Crops Research Institute (NRCRI),	KM 8, Umuahia – Ikot Ekpene Road, Umudike PMB 7006, Umuahia, Abia State 440001, Nigeria.	1923	The Institute is structured into divisions for efficient and effective management. These include Root Crops Research (RCR), Tuber Crops Research (TCR), Planning, Monitoring & Evaluation (PME), Biotechnology and Product Development, Farming Systems Research & Extension (FSRE), Information and documentation (I & D), Administration, Finance and Accounts, Engineering Maintenance and Estate Management.

15	Lake Chad Research Institute (LCRI)	P.M.B 1293, Gamboru Road Maiduguri, Borno State.	1960	Genetic improvement and development of production technologies for wheat, millet, and barley; the improvement of the productivity of the entire farming system in the North Eastern Zone.
16	Forestry Research Institute of Nigeria (FRIN)	P.M.B 5054 Jericho Hill Ibadan, Oyo State.	1954	The Institute is mandated to conduct research on the following: Conservation and improvement of genetic resources of forest trees and eco-system for economic development. Improvement of silvicultural practices relating to forest trees of economic importance. Mechanization and improvement of methods of cultivating, harvesting and processing of forest trees of economic importance. Improvement of the utilization of forest products and wood residues. Study of the ecology of pests and diseases of forest trees and their control. Development of agroforestry systems for the integration of forest trees of economic importance into farming systems in different ecological zones of Nigeria. Wildlife management and production. The socio-economic importance of forestry in the Nigerian economy. Forestry education and training. Forestry extension and dissemination. Sericulture. Any other problem relating to forestry flora and Fauna.
17	National Centre for Genetic Resources and Biotechnology (NACGRAB)	Moor Plantation, Ibadan, Oyo State, Nigeria.	1987	Established to conduct research, gather data, and disseminate technological information on matters relating to genetic resources conservation, utilization and

				biotechnology applications. The Centre, backed by Decree 33 of 1987 regulates the seed, livestock and fisheries industries through its Varietal Release Committees.

3.3 Agricultural research trials

Increasing agricultural productivity remains a central concern of developing countries. This is because it is a major factor determining the level of income of the farming sector, in meeting the food requirements of continually expanding populations, in generating foreign exchange to finance domestic programmes, amongst others. Agricultural research has an important role to play in meeting these targets; hence many of the new technologies, inputs, and techniques of production that increase agricultural productivity are developed through agricultural research.

In agriculture, scientists actively seek to discover procedures that will increase livestock and crop yields, improve farmland productivity, reduce loss due to disease and insects, develop more efficient equipment, and increase overall food quality.

Agricultural trials may vary but they have the common feature that they test whether changing something in a system alters the variable of interest, and by how much. An example might be checking whether adding a fertilizer to a crop at a particular time increases grain yield or the yield difference between varieties of a crop etc.

3.3.1 Types of Agricultural Research

a) On- Station-trials

This is the first level research usually conducted by scientists at their respective research stations. It is purely researcher-managed with little or no participation by farmers. For example, breeders’ seeds are first tested by the breeders on their experimental research farm. This type of research is normally carried at the university level or the research institute’s level

Features or characteristics of On- Station- trials

- Researcher managed
- Sited at the university/institutes’ research farm
- The area covered is small
- Farmers are not usually involved
- Fairly expensive
- Out-put is small eg breeders’ seed

1. On-Farm- Research

This level of research emerged from the fact that crops and their environments are highly complex systems with a multitude of variables that change from location to location in different degrees and on various time scales. Due to this complexity, practices optimized for a research station might not be so successful when transferred to another location. Though the new location may appear similar to the research station, there may be an undefined key limitation or combination of minor but different limitations that constrain production.

In many cases, carrying out a small-scale trial, actually at the new location, will lead to an optimal local farming practice more rapidly than trying additional sub-treatments at the research station.

Features of On-Farm- Research

- Away from research institutes' site
- Both researcher and farmer are involved
- Replicated treatments
- Small in size
- Location-specific
- Less expensive (use farm family labour)
- A control, which is what the farmer normally does - this control must always be included to compare or check against any treatment
- A design, that is, where treatments are positioned in the field and about each other

2. On-Farm- Adaptive Research (OFAR)

At this stage or point of research, we are already at the farmers' level with their full involvement. Usually, information from adaptive research programs is summarized into 'recipes' or protocols for crop production that do little justice to the increasing complexity of farmers' decisions or the large amount of useful information generated by mature research programs. A major challenge for exploiting the benefits of adaptive research is to find ways to synthesize and simplify information generated by research, into a form that can be effectively used by farmers.

On-farm Adaptive Research (OFAR) is one of the Agricultural Development Programme (ADP) activities used to develop recommendations for representative groups of farmers. From OFAR, then farm demonstration which is purely an extension activity aimed at convincing farmers to adopt the production recommendations that have emerged from the OFAR.

Features of OFAR

- Full farmers' participation

- A holistic approach
- Gender-sensitive
- Concerted multi-disciplinary investigation of farmers’ situations
- Involves the control (farmers’ practice)
- Few treatments involved
- Simple designs and layout
- Simple for the farmer to follow and comprehend
- Multi-locational
- Each farmer is a replicate though treated as a unit
- Cheap-farmers’ labour is used
- Critical input(s) supplied by government or its agency eg seed, fertilizer
- Most of the times, the yield belongs to the participating farmer
- Agency research staff/farmer-managed
- Inter-disciplinary
- Interactive and iterative
- Feedback to research centres.

3.3.2 Steps for the conduct of On-farm Adaptive Research (OFAR)

The five stages of On-farm Adaptive Research (OFAR) are described as follows:

Step I –Diagnosis
It implies studying farmers’ circumstances and practices to understand the farming system and system of interactions, identify possible productivity problems and begin to develop hypotheses on solutions of “What, How and Why”.

Step II –Planning
After identification of problems, planning is done involving the following steps:

- Prioritization of problems
- Study 4 or 5 most important problems at one time
- Develop problem-cause diagram
- Identify intervention points
- Decide the nature of intervention
- Listing of possible solutions of the problem
- Screening of possible solutions for system compatibility.

Step III –Experimentation
It includes the following aspects for experimenting on-farm adaptive

- Experimental sequence

- Design of on-farm experiments
- Selection of site and farmers
- Choice of farmers' practice
- Management of on-farm experiments.

Step IV –Assessment of results
There are 4 types of assessment i.e. agronomic, statistical, economic and farmers' assessment. No single assessment is complete in itself and there are no common denominators across different assessments. The farmers' assessment is final because they are the ultimate beneficiaries.

Step V –Recommendation
In case the farmers approve the solution of the problem studied, the technology can be recommended to the farmers having similar conditions. Therefore, each recommendation should specify the conditions where it can be appropriately adopted. If the tested solution is not approved, the problem should be referred to the research system for further investigation (feedback).

3.3.3 Constraints to the adoption of recommendations of agric research in Nigeria

We have noticed over the years that the fantastic outputs of research are often not reflected on the farmers' farms. There is this issue of 'expectation' not in tone with the 'reality' To close this gap, there is the need to shift from technology transfer to decision-making support. This implies that we have to analyse farmers' practices to understand their strategies and the technical, economic and social factors that influence their decision.

Below are the noticeable constraints in the adoption of research recommendations.

- Top-down approach in problem identification. Farmers should be the ones to tell the researcher his problems, some of which may not be technical. Participatory Rapid Appraisal approach comes handy in this regard.
- Most recommendations are in multiples eg plant density recommendations most at times come with fertility issues too.
- Some recommendations are outside the dormain of the farmer eg procurement of improved varieties from urban centres may not be easily feasible for the farmer.
- Generalized recommendations are often made for a large geographical area like an agro-ecological zone. This may not apply to some locations within the zone.
- Input dependent recommendations may not work for resource poor farmers.

- Some recommendations are beyond the technical ability of the farmer due to his limited educational background
- Some technological outputs are not marketable in the locations of the research. For instance, some varieties of crops may not be acceptable in some places and so marketing such research output becomes difficult, thus rejected. For faster adoption, there should be ready market for the research output.
- Government policies. Inconsistent policies discourage the adoption of technological recommendations. This is common when government is promoting the production of cash crops where policy and politics of the crop may discourage farmers.
- Corruption at all levels hinders adoption.

SELF-ASSESSMENT EXERCISE

Critically study the organogram of ARCN and attempt to reduce or shorten the layers of the structure to improve on the channels of communication. Which unit (s) should merge and which suggested sections or units should emerge to improve on organizational efficiency?

4.0 CONCLUSION

Over the years the challenge in agricultural technology generation, transfer and adoption is how to provide small scale farmers with relevant and adaptable information that can impact their decision-making process.

The increase in food production and food security through the improvement of productivity in both large and small-scale sectors is no longer the only issue that agricultural research and extension should look at. The competitiveness and quality of agricultural products, labour employment and income generation, equity and gender awareness, environmental concerns and management of natural resources also need to be taken into consideration. There is the need to build up new partnerships, to address these issues in a participatory and more efficient manner to satisfy the expectations of rural farmers.

5.0 SUMMARY

In agriculture, scientists actively seek to discover procedures that will increase livestock and crop yields, improve farmland productivity, reduce loss due to disease and insects, develop more efficient equipment, and increase overall food quality. On Farm Adaptive Research was designed to provide answers to the overall goals of agriculture. Agricultural researches are in stages, starting the scientists' thinking or concept which he tries at the research station. The positive outcomes are evaluated at the farm level. The government of Nigeria had been at the far front in agricultural research from pre-colonial to the present resulting in the establishment of foremost agricultural research institutes. Attempts have been made to involve farmers in the conduct of these researches but a lot has to be done to start the process at the farmers' level. In essence, there are many "improved technologies", although technically sound, but are not relevant to the socio-economic circumstances or even to the agri-climatic conditions of small-scale holders.

6.0 TUTOR-MARKED ASSIGNMENT (TMA)

1. List the features of On-Station-Trials
2. Name ten agricultural research institutes in Nigeria
3. From the abbreviations of the under-listed research institutes in Nigeria, give their full names and their respective mandates.
   - NIFOR
   - IAR
   - NVRI
   - NCRI
   - RRIN
4. List the steps required for the conduct of OFAR
5. Why are research recommendations not easily and adequately adopted by Nigeria Farmers?

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