THE DEVELOPMENT OF STABLE SYSTEMS OF FARMING[1]

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This review discusses factors which relate to the development of stability in farming systems with special emphasis on the problems of the humid tropics. Annual crops present a greater risk than perennial crops in terms of the need to avoid erosion ant to provide a continuing nutrient supply. The advantages of using crop residues for protecting the soil and of planting systems based on zero-tillage are emphasised.

Instability in livestock production systems is highlighted by the problems of desertification brought about through over-grazing particularly in areas of low rainfall such as on fringes of the Sahara Desert. It is proposed that an important factor is the development of systems, which allow feed to be stored or produced specifically as a buffer for periods of little or no rainfall. The advantage of sugar cane in this con text is stressed.

Particular emphasis is given to the role of nitrogen inputs and the effect of the energy a crisis on the cost of industrial fixation of nitrogen. The use of forage legumes as a means of reducing chemical fertilizer inputs is discussed and propoeals are put for wart for maximising the utilization of these crops both in terms of animal production and soil fertility. The question of nitrogen fixation is discussed ant it is considered to be one area meriting further research.

Key words: Cropping systems, stability, nitrogen inputs, forage legumes

Stability, or continuity in production, is a crucial characteristic of farming systems whether for the smallholder of the large-scale enterprise. Yet we have not been entirely successful in the past in designing new stable systems.

An examination of stability allows identification of its major comportents. and some of these will be discussed in relation to both crop pro auction and animal production systems.

A stable farming system is one in which output shows minimum variation. from year to year and in which this output is achieved without progressive increase in the amount of inputs required. It is probably not necessary to justify the importance of stability. For the smallholder with few resources behind him and often with little access to credit or to cheap loans, a system which ensures a regular food supply, or enough income to buy it, is more important than high average yield. He has little protection against risk. He may well assess and appreciate risk better than the technician who is advising him and the failure of the smallholder to adopt innovations proposed for him can be due to his greater perception of the risks involved. This can be a major and often unrecognised reason for what is described as his "resistance to change". Small farmers are very astute and are not usually slow to take up innovations in which they see real advantage.

Instability: Instability of output is of two types. Firstly, there is the situation where output fluctuates widely from year to year. In many parts of the world, rainfall variation is a major cause, but cyclical changes in pests and diseases and other natural hazards can also be implicated.

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Secondly, there is the kind of instability where yield shows a gradual decline over a period of years. In crop production this can, in many areas, be linked to the increasing pressures for continuous cropping systems which population growth has stimulated. Where population growth is a key factor, and perhaps in the tropics generally, the method of farming we most need and still lack is a stable system of continuous annual cropping.

Of course there are some excellent tropical examples of stable cropping. Paddy-field rice has been produced on some sites virtually every year for 2000 years or more. Perennial cropping with oil-palm or cocoa, or nearperennials like bananas and sugar cane can be equally stable. Shifting cultivation too can be stable, though in terms of land-use it is hardly continuous.

The stability of these systems is dependent on their ability to meet two essential needs. First is the avoidance of erosion and secondly the ability to provide a continuing nutrient supply adequate for the level of production, either with or without the use of fertilizers. In paddy rice production, the landscaping and the standing water, and the supply of biologically fixed nitrogen are the major factors creating stability. Perennial crops mimic the natural vegetation in providing continuous cover of the land, so restricting erosion. Their high transpiration rates reduce leaching of nitrogen which in an, case is only briefly in mineral, and there fore leachable, form as it cycles within the crop: veil system.

But where annual rain-fed cropping is the tradition, shortening of the resting phase in shifting cultivation can be disastrous because of the yield decline which may follow. Nor is this just a problem for the small farmer. There have been several attempts at large-scale continuous mechanised maize and grain legume production in Ghana over the years. Most if not all have been discontinued because of declining yields. Just as the small-holder without resources is dependent on a stable low-risk system, so the large scale mechanised producer is dependent on maintaining yields at a level which will meet his high input costs and still leave some margin. Declining yield due to steady erosion robs him too of stability, and it cannot be reversed by fertilizer use alone.

Crop residue mulching and zero tillage: This is why innovations which are under study at IITA in Nigeria are of such great interest to both types of producer. The technique is based on mulching with residues from the previous crop, coupled with zero-tillage planting techniques. Mulching is no new practice and its benefits in terms of water conservation, erosion control and soil temperature modification are well-known. Previous practices have used grass and other materials brought to the field, but this requires a great deal of extra work and the availability of an area from which mulch can be obtained. The use of crop residues avoids these problems and even relatively small residues can be effective as illustrated by Table 1.

Table 1:
Effect of ground cover on run off and soil loss for a 10 per cent slope (from Lal 1977)

Mean annual values	Bare ground	Mulched (6 t/ha straw)
Run off, % of rainfall	42	2.4
Run off, mm	504	29.3
Soil loss, t/ha/yr	232	0.2

Planting through the mulch without cultivation can be done by the smallholder using a modified "Jab-planter". Zero tillage drills are available for the mechanised farmer. The mulched and uncultivated soil has a greater organic matter content and more stable structure, with adequate permeability provided by the undisturbed root holes of previous crops and the increased population of soil fauna. Erosion is controlled, nutrient losses are reduced and the nutrient-holding capacity of the soil is increased.

Table 2 shows the yields for six crops of maize over three years at Ibadan. As the ratios indicate, in no year was the yield after zero-tillage less than after conventional. Although it is not obvious from these data, the report from which they come indicates that a reduction in yield occurs over time with conventional tillage but not on zero-tilled plots. Studies are continuing at a wide range of sites and climates.

Table 2:
Maize yields (t/ha) on zero and conventionally tilled plots on an Alfisol (from IITA 1978)

	Season	Conventional tillage	Zero tillage	Ratio zero/conv
1975	1	1.5	1.6	1.07
	2	1.1	1.2	1.09
1976	1	2,8	2.9	1.04
	2	1.2	1.6	1.33
1977	1	2,3	3.1	1.35
	2	1.6	1.7	1.06

Much remains to be worked out. The technique is probably better adapted to maize than to grain legumes (Lal 1976), perhaps because of the smaller residues that grain-legumes leave. It may not be appropriate for areas with a long dry season. It will require some use of herbicides for weed control, but the controlled droplet applicator or ultra low volume sprayer could be come readily available to smallholders. The whole technique can reduce to one tenth the labour required for land preparation, planting and weeding in conventional hand-tool cultivation systems.

This technique may not have much relevance for livestock feed production which can usually be based on perennial crops. But it illustrates the approach which can be adopted in trying to develop methods of production to fit particular physical conditions. Nevertheless, the technique could be valuable for the smallholder who both grows some of his food crops and keeps livestock, because it can reduce major work-peaks in his farming.

Desertification: In livestock production, instability of the type I have described is perhaps most obvious in the drier parts of the world. One example is the increasing desertification occurring on the fringes of the Sahara desert. Desertification can be defined as the development of a landscape of shifting sands and little vegetation in areas which did not previously have these characteristics. The southern border of the Sahara has in many areas moved 100 km south between 1958 and 1975, due to the effect of increasing human population on the ecological balance (Le Houerou 1977).

Inappropriate methods of crop production and the removal of woody vegetation for fuel are contributory causes but overgrazing is the main factor resulting in the agricultural output of some areas falling virtually to nothing. In these communities, welsh is often measured in terms of herd size rather than its quality or output and this is an attitude which will be slow to change. It is difficult to avoid the 'numbers' approach and to achieve appropriate grazing management where land or grazing rights are in common ownership, So schemes to develop individual or small-group rights aver land or the leasing of land, for example by Botswana in another dry part of Africa, are a step in the right direction.

But even without these extreme conditions, rainfall fluctuations are a major cause of instability or of wasteful feed utilisation. The farmer cannot easily adjust his livestock numbers and so his stocking rate will usually be kept at a level to match the feed supply in years of shortage, Even in England, it has been estimated that one third of the grassland in the south-east is essentially a reserve against drought. In all but the two or three driest years in ten it is under-utilized or not needed. So if livestock are to be kept at reasonable intensity and stability, the feed supply must be buffered against rainfall variation; by using irrigation, by having a reserve of stored feed, or by using crops which show some drought resistance. It is likely that a system based on cane production will be more tolerant of drought than one based on pasture grasses which have to be cut or grazed at frequent intervals and which for various reasons are therefore more prone to drought effects.

Nitrogen inputs: In addition to reducing yield fluctuations from year to year, and decline in yield over years, one should also try to buffer farming systems against economic instability. This can partly be achieved by diversification and the effective integration of different, perhaps crop and livestock, enterprises. But it also means making predictions about likely future changes in market demands and prices, and in the supply and cost of inputs. The input factor of particular and world-wide interest today is the likely future trend in the cost of nitrogen fertilizer. Industrial fixation of nitrogen is very costly in energy terms so that as energy supplies be come scarce and more expensive, perhaps from the mid-1980's, so fertilizer nitrogen will rise in cost. Indeed, this trend has already started.

In intensive farming, the support energy used to make nitrogen fertilizer can be as much as 30-50 per cent of the total support energy used. Of course, farming is a minor user of support energy compared with cooking transport and other industries but this will not prevent nitrogen fertilizer becoming more costly.

The off take of nitrogen in livestock production is not high. An intensive enterprise producing 8000 litres/ha of milk is removing from the farm only about 40 kg/ha of nitrogen. But if fertilizer is the only source of nitrogen for forage production, the farmer may have to use as much as 400 kg/ha of nitrogen as fertilizer, or ten times the amount he removes. So future stability in both farming and food prices will in part depend on economies in the use of nitrogen.

This has four implications. First, we must seek to make more effective use of fertilizers; we commonly recover in the crop only about half the nitrogen we apply, at best about two-thirds. This means better timing and more accurate prediction of the optimum application. Secondly, it may be possible to reduce leaching and denitrification losses. Thirdly, we must make more effective use of farm wastes. Lastly, we need to make greater use of biological fixation especially that provided by legumes and, for livestock feeding, particularly the forage legumes.

Forage legumes: Twenty five years ago forage legumes did not appear to have much of a place in tropical livestock production. One could hardly take that view now, even without the threat of increasing nitrogen cost. The first point to make is the wide range of morphological and ecological types now available (Skerman 1977). They show some variation in response to temperature and to water supply, though none are adapted to conditions of poor drainage. There are woody perennials, herbaceous perennials, and self regenerating annuals. There are procumbent and stoloniferous types tolerant of heavy grazing, and trailing and twining types which are better adapted to competing with tall-growing grasses. Most of the forage legumes are not very tolerant of shade, but there are a few which show some adaptation. Many of the commercial species are self-fertile and therefore show good varietal stability. A few like Desmodium heterophyllum are good grazing plants, but have poor seed production characteristics and have to be vegetatively propagated. Apart from some 'hard seed' problems most of the forage legumes can readily be established from seed, though early growth is usually slower than the grasses.

It must therefore be an important task in developing ruminant production systems to examine the suitability of different forage legumes for the local circumstances of:

a) soils and climate
b) different utilisation needs, e.g. grazing, cut feed, conservation
c) for integration with other local feeds, both in terms of seasonality and nutritive value.

The forage legumes often show a lower acceptability to livestock than the grasses, but even this can sometimes be an advantage. Hood (1972) working in Zambia found that the prime need in beef production was an improvement in the quality of dry season grazing, He achieved this first through the foliage growth of lopped browse trees but he also studied a number of forage legumes which might be sown into existing natural grazings. Stylosanthes guanensis proved the most appropriate: it was more productive than the others he examined, it was partly rejected in favour of the grass component during the rains and so its foliage remained to improve the quality of dry season grazing. Thus a situation in which indigenous cattle on natural grazings lost weight for five months of the year and gave an output of 100 kg/ha/yr was altered on legume improved swards to a weight loss for only three months of the year and an output of 180 kg/ha/yr.

Another development of importance here is in our ability to sow improved species into existing pasture. Frequently, the better classes of land are best used for cash and food crop production and much of the live stock feed must come from natural grazing on land which for one reason or another is difficult to cultivate. Equipment is being developed in different parts of the world which can achieve this, using various sod-seeding techniques with or without local application of a herbicide, according to the conditions.

Nitrogen fixation: If we are to get the maximum out of forage legumes we must pay special attention to the process of nitrogen fixation. Temper ate species seem in general to be well-supplied with reasonably effective naturally-occurring strains of Rhizobium. But according to Obaton (1977) it is very common to find field-grown forage legumes in the tropics infected with strains of low effectiveness. So any legume programme must be accompanied by nodulation studies. The variation in effectiveness can be very large. Bergersen (1971) in Australia collected some hundreds of isolates of Rhizobium trifolii and tested them on a genetically uniform cultivar of Trifolium subterraneum. The dry matter yield of the clover varied with the isolate by as much as a factor of eight, and the mean yield of all of them was only half that of plants inoculated with a commercial strain of Rhizobium. Thus, inoculation may be a very important part of pasture establish meet.

The entry of Rhizobium organisms is an infection process, and once infection by one strain has occurred the legume may be virtually immune to others. Unfortunately, the most aggressive and competitive strains of Rhizobium are not always the most efficient nitrogen fixers. Where a naturally-occurring strain is aggressive in infection but poor in fixation, inoculation with a better strain can be difficult. Dart (1977) comments that new methods of inoculation may increase the competitive ability of the inoculum strain used.

There are many examples in the literature of fixation rates in forage legumes of 100 to 200 kg/ha/yr of nitrogen. These and greater quantities should be possible if we give attention to the matters discussed above, and to the whole question of selecting compatible combinations of legume cultivar and Rhizobium strain because this is an area which has received so little study in the past.

Innovations on the farm: The methods of farming we develop must not only be in tune with the local conditions of land and climate and the local economic conditions, but they must meet the aims and circumstances of the farmer, must avoid unacceptable risks, yet exploit his entrepreneurial abilities. In transferring technology to the farmer, it is particularly important to know whether the response to an innovation or whether the out put from an enterprise is likely to be the same on the farm as it is on the research station. There have been few studies on this topic but one in Australia by Davidson and Martin (1965), examined both crop and animal production. They found that on farms adjacent to a research station , animal production per hectare was approximately half that of the station, and that the effect of particular treatments was twice as great on the research stat-ion as on the farm. So the farmer may achieve only half the effect that the research worker achieves.

This cannot be a fixed ratio but it does mean that technology must be carefully evaluated before it is proposed for general use. There must there fore be close links between the research worker and the extension officer and perhaps too between the research worker and the farmer. The farmer's confidence in both can be very easily destroyed by advice which turns out to be inappropriate.

The development of new stab]e systems of farming must therefore include farm-scale testing under realistic conditions before research studies can be safer`, translated into farming practice.

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