16 Integrating crops and livestock in southern Mali: rural development or environmental degradation?

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16.1 Introduction

This chapter could have had a second subtitle: 'It ain't necessarily so', inspired by the song from the folk-opera *Porgy and Bess*: 'The things that you liable to read in the Bible, it ain't necessarily so'. For me, not a student of de Wit's, not even a modeller, this motto characterizes my attitude towards him and made research under his guidance inspiring. Moreover, I am convinced that such an attitude to models and simulation is a prerequisite for their fruitful use. In this chapter I will illustrate the usefulness of models and systems analysis for policy-supporting research on rural development and attempt to provide building blocks for a bridge between socio-economic and agro-ecological research for rural development.

I will present an example of more rapid problem identification. The present situation in rural southern Mali will be described, based on the results of simulation of rangeland (Penning de Vries & Djitèye, 1982) and crop production (SOW, 1985). If sociologists and economists working on rural development in the region would accept this description, confidence in the use of simulation models would increase. That is another prerequisite for fruitful application of models in rural development, especially in situations as difficult as those in the Sahel.

I will go on to suggest possibilities for rural development in southern Mali, paying special attention to the option originating from local farming systems research: integrating crops and livestock. Maybe disciples of de Wit will conclude that 'it ain't necessarily so'. This should provoke them to formulate improved suggestions, thereby decreasing the need for expensive and disappointing trial and error to arrive at sustainable agriculture for the Sahel.

16.2 Problem identification in rural southern Mali

16.2.1 The region

Southern Mali is selected because of data available, but the area is also characteristic of the landlocked, poorly opened Sudan savannah of West Africa. Southern Mali covers an area of almost 100 000 km^2 between 10° and 14° N and 4° and 8° W. Average rainfall over the last 30 years ranged between 700-1200 mm yr^{-1}, which under the prevailing conditions results in a growing season of 4-5 months.

The 2.8 million inhabitants live in almost 4000 villages whose distribution is very heterogeneous and is related to the suitability of land for agriculture, which is determined by rainfall and soil properties. In the centre and the north, where on average 50% of the land is suitable for arable farming, population density correlates positively with land suitability (Table 19). The correlation may be influenced by data availability: only population densities per municipality are available.

In the south, where 70% of the land can be cultivated, population density is, however, only about two-thirds of the regional average (20 against 30 persons km^{-2}; PIRT, 1983). This trend continues further south into Ivory Coast, population density decreasing with increasing annual rainfall (Bengaly et al., 1988). Here, land suitability no longer correlates positively with water availability, as leaching of nutrients becomes important. River blindness and sleeping sickness are other reasons for the lower population density.

The landscape is a tableland traversed by temporary and permanent small streams and rivers, with valleys of various widths. The soils on the plateau are shallow and stony. On the slopes they are deeper, but with lower infiltration capacity, causing runoff. As a consequence, in general only the valley bottoms can be cultivated without too much risk of crop failure and lack of sustainability.

Official statistics on land use are rather unreliable (Breman & Traoré, 1987), but on the basis of interpretation of satellite images (PIRT, 1986) and personal observation, it has been estimated that about 25% of the total land area in the region is cultivated, except in the very south, where only about 10% is cultivated. Fallow land also accounts for about 25% of the area. Villages and roads, mostly in the valleys, account for more than 10%. This implies that in the centre and the north of the region all suitable land (about 50%), including fragile soils, is already in use.

Table 19. Population density in relation to the suitability of the land for agriculture in the Sudan savannah in southeast Mali. Each density class is characterized by the relative importance (%) of six suitability classes. Suitability increases from top to bottom.

Persons km^{-2}	<5	5–10	10–20	20–50	>50
Area (%)	7	24	42	24	3
Rocks or water	15	10	5	4	1
Sandy	16	4	3	6	5
Plains; fine loam or clay*	39	24	26	26	19
Lateritic subsoil	27	59	52	35	32
Flood plains	2	2	5	9	25
Plains; loamy sands*	1	1	4	11	17

* Plains soils of heavy texture have a low suitability because of drainage problems and workability.

The major crop is sorghum, followed by millet, peanut, maize and others. About 10% of the cereal production is marketed, mostly on the domestic market, compared with about 50% of the peanuts and all the cotton, which is exported. This implies that about 80% of the cultivated arable land is in use for regional consumption.

Livestock is becoming increasingly important, with animal traction and manure as the major products (Breman & Traoré, 1987). An unknown number of livestock owners, often wrongly overlooked by development projects, migrated from the Sahel during the drought and are trying to use the waste lands of the region in competition with the sedentary herds of the arable farmers.

The CMDT (Compagnie Malienne pour le Développement des Textiles) constitutes a major factor in rural development in the region. This state organization was responsible for the development of cotton production in all its aspects: extension, supply of credit, fertilizers, pesticides and agricultural implements. purchase and processing of cotton and marketing of fibre, cotton seed and cotton cake. CMDT is at present responsible for total rural production, including animal husbandry. Rural development as such has become the final goal: crop diversification, public health, literacy, erosion control and the position of women are all receiving attention.

Cotton production has increased spectacularly since 1960 (from 2000 to almost 70 000 tons of fibre per annum), demonstrating that farmers adapt with surprising speed. The cereal yields of the region are amongst the highest of the country indeed, but their increase has been limited. For the country as a whole food production has not kept up with the expanding population. As a consequence, commercial imports and food aid are steadily increasing, testifying to the increasing dependence on food from abroad (OECD, 1988).

16.2.2 Socio-economic bottlenecks

Before discussing the bottlenecks to rural development in the region, the term 'development' has to be defined. For the time being 'increasing well-being of the population' will suffice. This is an elusive definition, but a more explicit description will be possible after the analysis presented in this section.

The socio-economic bottlenecks to development that have been suggested are so numerous and diverse that they can be treated here only superficially. As a consequence, in most cases the evidence presented here refers to the entire Sahel region, instead of to southern Mali only.

In certain bottlenecks social aspects dominate. The disruption of societies by over 60 years of colonial rule and its negative consequences is blamed for the loss of efficient production systems, the loss of traditional knowledge and land use regulations, the artificial frontiers, the introduction of cash crops and the disintegration of family structures (e.g. OECD, 1988; Bassett, 1988). Cash crops are probably the most frequently blamed. They occupy the best soils, pushing food production to marginal soils and, indirectly, animal husbandry into the dessert (e.g. Franke, 1987; Franke & Chasin, 1980). A quotation from 1915 is illustrative of the French colonial policy: 'If we try to develop cotton, it is to provide an export trade with a raw material, while facilitating import of European cloth. Hence, the native must be persuaded from the outset to deliver his cotton to commercial houses so that local weaving will gradually be suppressed' (Bassett, 1988). Social inequality is another major bottleneck. It embraces the position of women, the neglect of the rural population by authorities and the loss of control over the means of production by the original producers (e.g. Breman & Traoré, 1987). The growing inequality aggravates the situation and partly explains the failure of development programmes aiming at aiding the poor. The suggested lack of responsibility of farmers is a special case (e.g. Franke, 1987). Closer examination of this argument reveals that it may have various interpretations. Either, they will have to learn how to behave, or they have to pay for all services, or advantage should be taken of their skills. The relative rigidity of rural production systems and lifestyle is also considered to hamper development (OECD, 1988; Giri, 1983).

Various economic bottlenecks, have also been recognized (see Breman & Traoré, 1987). Government policy on taxes, subsidies, prices, imports and exports provides insufficient incentives to the farmers to produce (e.g. Delgado & Staatz, 1980); indeed, the government's entire financial policy is open to criticism. Furthermore, marketing structures and the distribution of revenues are far from optimal (e.g. Harriss, 1982), and the international situation (e.g. world market developments, policy of the European Community, restrictions imposed by the International Monetary Fund or donors) is not favourable either.

This list is by no means exhaustive and the problem is that it becomes increasingly difficult to see the wood for the trees. There is lack of hierarchy, a headache for modellers.

16.2.3 Agro-ecological bottlenecks in relation to socio-economic bottlenecks

It is interesting to consider the bottlenecks listed above in relation to the development priorities for southern Mali formulated by the Malian Department for Farming Systems Research (DRSPR). These are: integration of crops and livestock with strong emphasis on animal traction and manure production, strengthening rural extension, erosion control and improving the position of women. Do these priorities reflect an order in agro-ecological and socio-economic bottlenecks? Closer examination shows rather the reverse. Several of the bottlenecks listed above are recognized, but considered impossible to remove by on-farm research. Animal traction and manure are advocated because the farmers are ready to accept them: there is a shortage of land and fertilizers are expensive. Erosion control could be in line with the priorities of farmers, but the women's programme is certainly a 'top–down element'. However, DRSPR does not examine its priorities in relation to existing bottlenecks, nor does it consider the adequacy of traction and manure as production targets against ecological criteria in the long run. Hence, the development priorities for southern Mali have

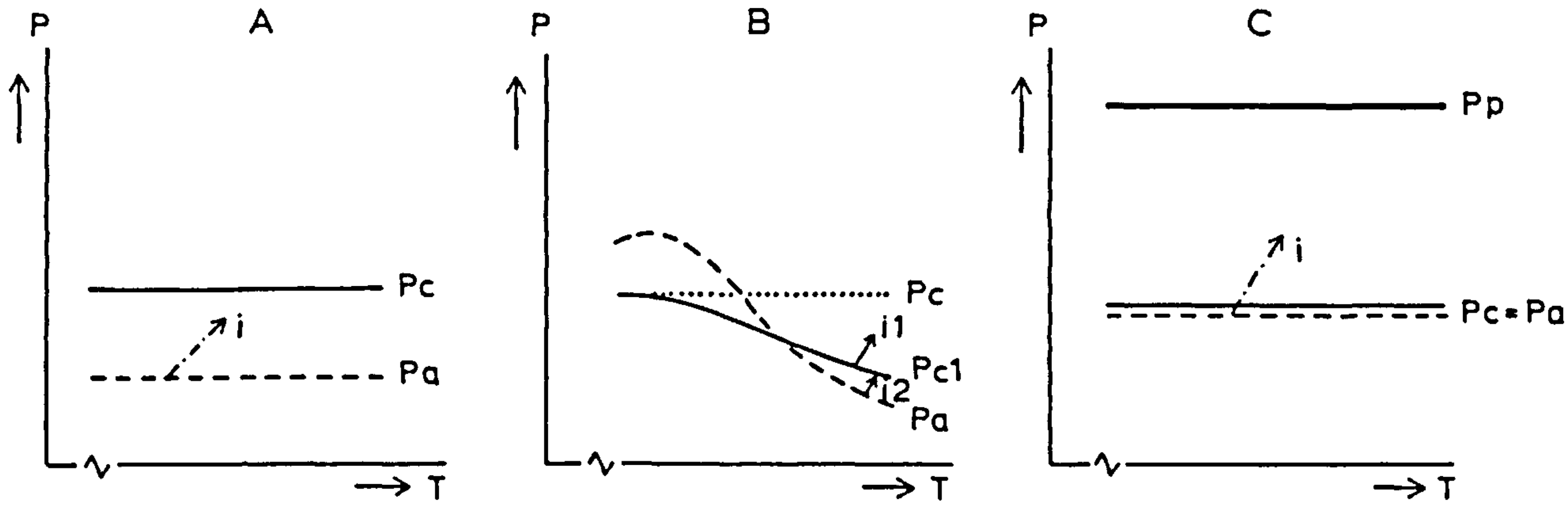

Figure 86. Schematized presentation for the identification of possible development interventions (*i*), on the basis of comparison and analysis of the level of agricultural production at the carrying capacity of the natural resources (*Pc*) and the actual level reached by local production systems (*Pa*). A: underexploitation. B: overexploitation. C: maximum exploitation (*P*: production of crops, pastures, forests, water, etc.; *T*: time; Pp: potential production as determined by climatic conditions and genetic potentials of species and varieties).

been set rather arbitrarily.

Systems analysis and modelling can help to work less intuitively, to identify and classify bottlenecks, as is illustrated in Figure 86. An agro-ecological analysis is needed to establish whether a region is underexploited (A), overexploited (B) or used optimally (C). The maximum level of sustainable production at the current level of inputs (*Pc*) has to be determined by systems analysis, which also must identify the major constraints. The actual level of production (*Pa*) must be derived from farming systems research, which should also identify the factors determining it: is underexploitation the result of ignorance or social inequality? Is overexploitation a consequence of irresponsible behaviour, of ignorance or of circumstances beyond control of the local population, considering overpopulation? What is the major constraint to increased carrying capacity of the natural environment: lack of skills, lack of the necessary means of production or lack of economic incentives to use them? Whatever the reason, if the production capacity cannot be increased, optimum resource utilization easily turns into overexploitation under increasing population pressure. Different interventions (*i*) are necessary in all these cases.

16.2.4 Analysis of the situation

Applying the approach outlined above, southern Mali appears to be a region where overexploitation is rapidly increasing as a result of overpopulation, especially in the centre and the north (Breman & Traoré, 1987; Berckmoes et al., 1988). This is illustrated by comparing the 'average' production system with an intensified system as practised by 20% of the farmers in the region (Table 20). The data for the intensified system refer to a group of 9 farmers, studied over a 6-year

Table 20. Comparison of the average production system in southern Mali with an intensified production system (characteristic for 20% of the farmers).

	Average	Intensified system	
		1983	1987
ha person^{-1}	0.4	0.8	0.8
Crops			
cereals (%)	58	50	54
cotton (%)	14	45	43
legumes (%)	11	3	3
sundries (%)	17	2	–
Inputs			
ha plough^{-1}	7	6	5
N fertilizer (kg ha^{-1})	5	27	20
livestock (TLU** person^{-1})	0.3	1	1
rangeland (ha TLU^{-1})*	7	4†	3†
Yields			
cereals (kg person^{-1})	225	285	370
cotton seed (kg person^{-1})	70	515	520
leguminous fodder (kg TLU^{-1})	230	85	65

* without nomadic herds; ** Tropical Livestock Unit; † if system should not use more rangeland per farmer than the 80% less intensified systems.

period (Berckmoes et al., 1988). To show that the farmers behave rationally in the present situation of overpopulation, recent developments in the intensified system are also illustrated.

The average production system concentrates on cereals. At the current production level at most 10% can be marketed, assuming a subsistence need of 200 kg person^{-1}yr^{-1}. Production of cotton is limited and the use of fertilizers negligible. As the ratio cultivated land/fallow is 1:1 (Subsection 16.2.1), there is a danger that arable land will be rapidly exhausted and degraded. For the rangeland the situation seems more favourable: 7 ha are available per tropical livestock unit (TLU, a standard ruminant of 250 kg liveweight), at a carrying capacity of 5 ha TLU^{-1}, if all crop byproducts are used on the farm and no other herds graze the waste lands (Breman & Traoré, 1987). Currently, however, herds originating in the north exploit the region and most of the cotton seed and part of the peanut byproducts are used elsewhere. The availability of ploughs and draught animals is another threat for the rangeland.

In practice, large deviations from this average situation occur. The Department for Farming Systems Research distinguishes three classes of farmers in their on-farm research, based on ownership of agricultural implements and cattle. Type C production units do not own ploughs or draught oxen, Type A units are well equipped and own a herd of at least 20 head of cattle. Type B is intermediate. The poorly equipped production units often borrow implements in exchange for labour, which endangers the timeliness of their operations. Therefore, the A unit yields are higher than those of C units, but within this last group exceptions do exist: for example old respected farmers assisted by Type A farmers (de Steenhuijsen Piters, 1988).

The data in Table 20 for the intensified (Type A farmers) indicate possible real intensification: compared to the average system there is higher production per person, more fertilizer use and a higher degree of mechanization. In addition, the production of the cash crop cotton is higher, both in area and in yield per unit area; manure availability is only slightly higher, animal density per person is three times higher, but the cultivated area per person is double. The carrying capacity of the rangeland, however, is clearly exceeded and it is unlikely that the amount of fertilizer used is enough to maintain soil fertility.

The trend from 1983 to 1987, i.e. less cotton and more cereals, less fertilizers and increased mechanization and herd size, is the result of two extremely dry years, which affected food production much more than cotton production, and higher prices of pesticides and fertilizers on the local market and a fall in cotton price on the world market.

The sustainability of the production systems in southern Mali has already been questioned. That doubt increases when the nitrogen balance of the arable cropping component of these systems is examined. Neither the average system, nor the intensified system is in equilibrium (Table 21). The terms of the nitrogen balance presented here were quantified on the basis of the results obtained in the project 'Primary Production in the Sahel' (Penning de Vries & Djitèye, 1982).

It was assumed that all cereals produced above the level of self-sufficiency are sold, in addition to half of the peanut seed and 70% of the cotton seed. Moreover, all byproducts (leguminous fodder, cereal straw, 30% of the cotton seed, bran, etc.) were assumed to be consumed by the own herd. Cotton stalks and leaves, however, are completely burnt. Without burning, losses occur by volatilization and are about half. Runoff lossed were assumed to be proportional to water losses, i.e. 20% of the N input by rainfall and algae; losses by leaching were calculated as a fraction of the available mineral N, proportional to the fraction of infiltrated water percolating below 2 m. Erosion losses were estimated to be 5 kg ha^{-1} yr^{-1}, i.e. 13 000 kg of topsoil containing 0.4% N (Kessler & Ohler, 1983) for the intensified system, and for the average system with a lower degree of mechanization 3 kg ha^{-1} yr^{-1}. Losses of N from manure and fertilizer were neglected.

In the intensified system losses are even higher than in the average system, because of the export of cotton seed and increased losses by runoff, leaching and

Table 21. Nitrogen balance (kg ha^{-1} yr^{-1}) of cultivated land of the average production system in southern Mali in comparison with an intensified system.

	Average	Intensified system	
		1983	1987
Inputs			
rainfall, algae	9	9	9
leguminous crops	4	3	2
manure	3	7	7
fertilizers	5	27	20
Total	21	46	38
Outputs			
sales:			
• cotton seed	3	16	16
• peanuts	1	1	–
• cereals	1	2	3
consumption losses:			
• people	4	2	2
• livestock	13	12	13
runoff, leaching, erosion	8	15	14
fire	4	19	19
Total	34	67	67
Balance	−13	−21	−29

erosion, and by the burning of straw. The situation has deteriorated since 1983 as a result of the restricted use of fertilizers.

The data in Table 21 corroborate the conclusion drawn from Table 20: sustainability of land use in the region is threatened by overexploitation, which presents a great danger to the region and the country. Self-sufficiency in food production is becoming more unlikely, and the production of the most important cash crop is in danger, with serious implications. To cope with population growth, intensification of crop production is required through the use of imported inputs, which are more profitable for cotton than for food crops because of the low and decreasing purchasing power on the national market. In other words, cash crops are necessary for rural development aiming at self-sufficiency in food production. However, limited use of fertilizer for economic reasons, and export of cotton seed and peanut cake out of the region (Table 21) hamper that development.

The analysis enabled the various agro-ecological bottlenecks and different socio-economic constraints to be identified and arranged in order of priority. To convince those not acquainted with modelling and systems analysis, the relation between the conclusions and the assumptions underlying the model must be explicitly formulated. Simplification is both the strength and the weakness of modelling and systems analysis (Seligman, Chapter 14). For outsiders, even if they understand a model, it is practically impossible to judge the limits of its applicability and hence the validity of its results. To illustrate this, two examples will be given. First, when discussing Table 20 it was concluded that a grazing pressure higher than 5 ha TLU^{-1} signifies overgrazing. That conclusion is based on production capacity in dry years, at the current ratio of cattle and small ruminants, with maintenance of the herd as production goal; in other words, environmental criteria were not considered (Breman & Traoré, 1987). Secondly, when estimating the losses of N (Table 21) an average value of 50% was used for consumption losses for food and for fodder, for men and animals. However, losses from urine varying between 20 and 90% have been reported (Penning de Vries & Djitèye, 1982)!

However, if specialists cannot falsify the conclusions on the basis of better local parameters, and if generalists cannot falsify them by indicating the possibilities for higher outputs without resource degradation, the current analysis is the best available. In that case, four considerations are important for the precise indentification of socio-economic bottlenecks:

- economic criteria increasingly influence behaviour
- prices of agricultural products and means of production, both at the farm gate and at the national border are of prime importance
- the question who controls the use of the natural resources needs more attention
- family planning and alternative employment have to be considered.

This short list raises the question of whether attempts to promote rural development should be directed at the farm level or at the policy level. The analysis also casts doubts on the appropriateness of the approach of the Department for Farming Systems Research at the farm level, with its emphasis on animal traction and manure. Because of the shortage of rangeland and high quality crop byproducts this approach results in increasing inequality, rather than being a solution for the poor by providing cheap alternatives to tractors and fertilizers. 'There are signs of an emerging class of rich farmers, each owning several pairs of animals and several animal-drawn implements, using more productive techniques than 'traditional' farmers and employing wage-earners' (OECD, 1988).

It is not clear whether this growing inequality is a constraint or a necessary condition for development. Hence, clarifying that point should be a priority for socio-economic research, in addition to research aiming at removing the bottlenecks indicated. Both the fact that in the intensified systems more cereals are produced for the national market than in the average systems, and the necessity to produce in a competitive way for the world market should be taken into account. The key question to be addressed by such research has to be to what extent the exploitation of people prevents the optimum exploitation of the natural resources.

16.3 Development policy and research requirements

16.3.1 Definition

Identifying the bottlenecks is not sufficient to formulate the policy needed for development, without a more explicit definition of 'increased well-being of the population'. The latter was clearly put into words by a Sahelian nomad: 'We were never as miserable as this year. No more cattle, no animal husbandry, no milk. No community life according to our tradition, no friendship, no charity. Everybody is only concerned with his own stomach' (Maliki, 1984).

Consequently, increased agricultural production and increased sustainability have to be pursued; not only for the region but also for the much less endowed rest of the country.

16.3.2 Integrating crops and livestock

Integration of arable farming and animal husbandry in itself is not a solution. Using systems analysis, the area of rangeland needed per hectare of cultivated land for different animal production targets was calculated (Table 22; Breman & Traoré, 1987). It is already difficult to feed draught oxen adequately in parts of the northern savannah, because of the intensity of arable farming (25% in the north, 10% in the extreme south). Breeding draught animals presents more difficulties, and maintaining soil fertility is impossible everywhere if carrying capacity is respected and import of livestock from outside the region is impossible.

Table 22. Rangeland requirements (ha) per ha of cultivated land for different production targets in the savannah region of Mali.

Zone	Production Target		
	feeding draught oxen	breeding and feeding draught oxen	breeding and feeding draught oxen + maintaining soil fertility
north savannah	0.5–4	10	15
south savannah	0 –2	8	15

Availability of agricultural byproducts was only considered in detail in the case of proper feeding of draught oxen: the lower number in Table 22 refers to their complete use by the oxen, the higher number to the situation were only cereal straw is available as the legume straw is sold or fed to sheep, cotton seed is exported and cereal chaff is fed to chickens.

If integration of extensive arable farming and animal husbandry does not lead to increased production using sustainable production techniques, intensification is unavoidable. The current prices of agricultural products and means of production imply that intensification is economically more attractive in arable farming than in animal husbandry. That should ultimately lead to a situation where instead of crop production profiting strongly from animal husbandry, the reverse will be true because the increasing availability of high quality agricultural by-products will enable a significant production of animal protein on the low quality rangelands of southern Mali (Penning de Vries & Djitèye, 1982), where today practically only production of manure and animal traction is feasible. The first production systems to be considered in that context would be systems with a short cycle, like poultry, that can take advantage of surplus production, of which the frequency will increase through intensification, to avoid crashes of cereal prices.

More direct intensification of animal husbandry could be remunerative through the production of draught animals for the regional market or for export, and for dairy farming in the vicinity of cities.

16.3.3 Intensification of agriculture

With respect to intensification, two general questions are to be answered: 'which form of intensification and where to improve the situation in a sustainable way?'. De Wit has argued in favour of intensifying agriculture on the most favourable soils (de Wit, 1972; Chapter 17) on the grounds that under those conditions inputs are used most efficiently, and hence production is most economic. Recently, de Wit (1988) demonstrated that such developments have indeed taken place in the European Community and that this leads to marginalization of the less endowed regions, which requires, at least, social programmes that may include stimulation of agricultural activities to prevent complete destruction of such societies (de Wit et al., 1987). I agree that the efficiency of inputs increases superproportionately with increasing production potential of the land (Figure 87), but I do not conclude that therefore agricultural development should necessarily only be promoted in those areas. Several arguments can be used against such a policy.

- Although the negative influence of intensive agriculture on the natural resources will be lowest per unit of product, for the time being it is the highest per unit area (de Wit, 1988).
- The observed yield increases are strongly governed by the socio-economic conditions under which production takes place, which in developing countries are far less favourable. In addition, if environmental costs, associated

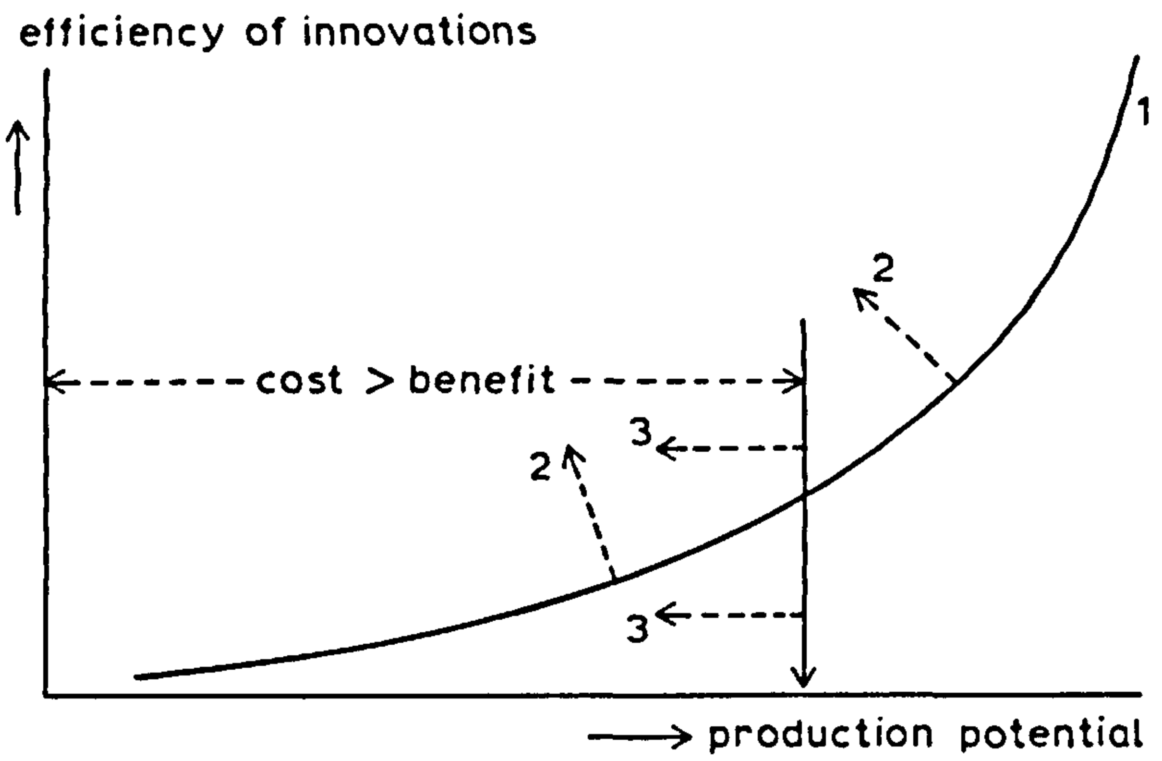

Figure 87. The most probable relationship between the efficiency of innovations from private efforts in a liberal environment (1) and the production potential of land (determined by the natural environment in its socio-economic context) and the direction to be given to agro-ecological research (2) and socio-economic policies (3), to avoid marginalization of people, regions or countries by these innovations.

with intensive production would be taken into account, the costs of production may well be higher than in less intensive systems, where more natural functions of the environment are still vigorous. In addition, increased skills will be required of the farmer, leading to higher labour costs.

- It will be difficult enough to have the suggestion accepted within a country or within the European Community the level to which de Wit et al., (1987) address themselves. The market where producers operate also limits the region where solidarity is maintained. This is the EC as a whole for the EC-countries but for many developing countries it is the country as such. 'Less favoured' and 'better-endowed' regions are relative notions, as the best conditions in one country may be equal to the worst in another.
- Supporting subsistence agriculture may be the cheapest social measure for marginal areas, especially when also considering the additional social benefits for society as a whole, e.g. the slowing down of urbanization.
- Social measures imply dependence, a notion incompatible with well-being, and the more so the more direct this dependence is.

It is therefore worthwhile to also pay attention to less favoured regions, and to investigate at least the possibilities for appropriate agricultural intensification. That implies that socio-economic research and measures must aim at pushing the break-even line in Figure 87 to the left. The cost-benefit ratio could be influenced directly by national policies or international agreements and support, or indirectly by influencing the input/output ratio through proper incentives in areas such as tenure systems.

An original agro-technical option to reach the same goal was de Wit's idea to use zeppelins to distribute phosphates which, in terms of Figure 87, is equivalent to shifting the x-axis to the right. In general, agro-ecological research and interventions should try to make the curve in Figure 87 less concave. That is not equivalent to suggesting 'natural alternatives' for intensive agriculture (Table 23) for the poor farmers in the Third World, even though such suggestions seem attractive because of the high costs of inputs for intensive agriculture, the growing dependence on using them and the existence of fascinating local alternatives based on effective use of natural resources (e.g. Franke, 1987). However, the potentials of these alternatives are often overestimated, because the constraints presented by the current situation are ignored, and their costs in terms of capital and labour are underestimated (Breman, 1987).

To properly judge the scope for improvements, research should at least be directed towards optimum use of inputs like fertilizers and irrigation, not only for cash crops but also for crops cultivated primarily for subsistence. That requires an improved research methodology: instead of the single dose–effect experiments yielding time- and site-specific results only, modelling and simulation techniques should be used to increase insight in the underlying processes so that the results

Table 23. Indications of environmental conditions that guarantee optimum efficiency for agricultural elements regarded as 'natural alternatives' for intensification through the use of external inputs.

Production systems	Soil					Climate		
	fertility			water-holding capacity		water availability		
	low → high			low → high		low → high		
increased availability of water and/or nutrients:								
• manure			+	+				+
• legumes	+				+		+	
• agro-forestry	+			+		+		
decreased losses of water and/or nutrients:								
• agro-forestry			+	+				+
• erosion control:								
– wind			+	+		+		
– water			+		+			+
• water harvest			+	+		+		
• mixed cropping								
– pest control			+		+			+
– drought		+		+			+	
• adapted varieties	+			+		+		+

can be used for extrapolation and prediction (van Keulen & Wolf, 1986). For instance, results from PPS (Penning de Vries & Djitèye, 1982), SAFGRAD (PIRT, 1986) and the Agro-Meteorological Service of Mali (Traoré & Konaté, 1989) clearly show that data used to estimate the returns on fertilizers (Annual reports of the Department for Farming Systems Research) are not realistic. Rather, they show lack of insight in the conditions of the zone and the basic processes.

16.3.4 Integrated agriculture

When trying to develop methods to intensify agriculture in sub-optimum zones, it is dangerously naive to copy the Western example. The latter developed without serious incentives for economizing on the use of inputs like fertilizers and pesticides and without general awareness of the environment. But disregarding the production potentials of the Western example would also be unwise, in view of the still growing demands for food. Mixtures of elements of intensive agriculture and 'natural alternatives' might lead to a more favourable shape of the curve of Figure 87.

To make this plausible, an attempt has been made to break down the x axis of Figure 87 into its basic elements: the suitability of a region for intensive agriculture depends on soil fertility, soil water-holding capacity and water availability as dictated by climate. Their rough relation with the efficiency of intensive agriculture is presented in Figure 88.

The optimum conditions for natural alternatives are not necessarily identical to those for intensive agriculture. Some of the 'plusses' in Table 23 are self-evident, other were chosen rather subjectively and could probably be questioned by specialists.

Given that for some of the conditions the optimum for natural alternatives is different from that for intensive agriculture, combinations of both, so-called integrated agriculture, may have optimum conditions different from those for intensive agriculture alone. At least the range of conditions under which potential production can be realized is extended (Figure 89). Hence, the curve resulting from a combination of the relations for soil fertility, water-holding capacity and water availability will be less concave than that of Figure 87.

The intensified system presented in Table 21 uses only some tens of kg ha^{-1} of N in the form of manure and fertilizers. Half the amount is probably unnecessarily lost by runoff, leaching and erosion. Programmes like those of the anti-erosion project in the zone (Hijkoop & van der Poel, 1988) require investments in human efforts and capital that are not profitable in the average system, in which only 8 kg ha^{-1} of N is lost (Table 21). Hence, the more intensive the system, the greater the profitability of such measures.

The proportion of legumes in the rotation decreases with 'intensification' (Table 20), though the Department for Farming Systems Research recommends cultivating cowpea to improve the diet of draught oxen. Berckmoes et al. (1988)

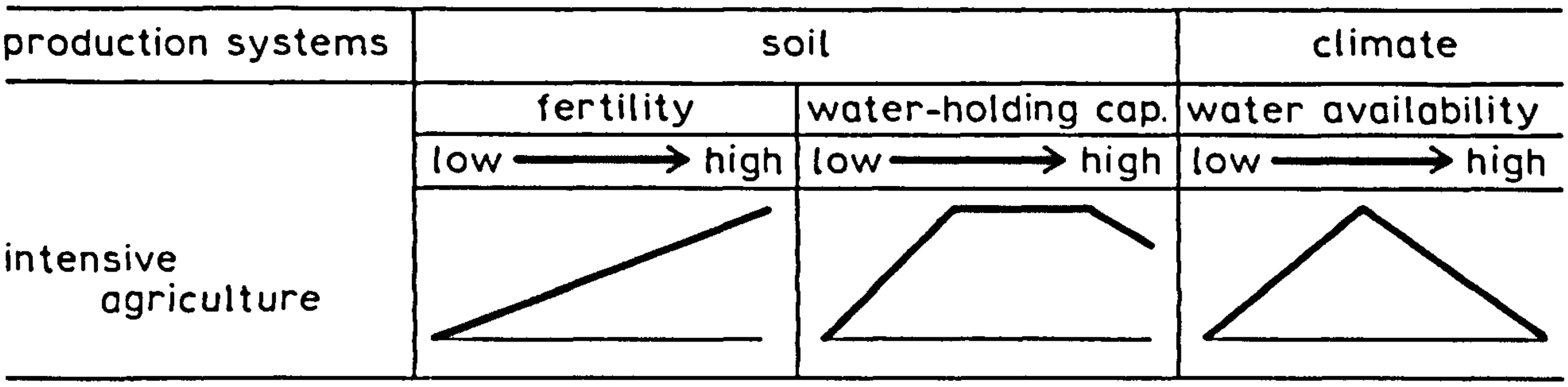

Figure 88. The production efficiency of intensive agriculture in relation to the potential of the environment, specified for soil and climate parameters.

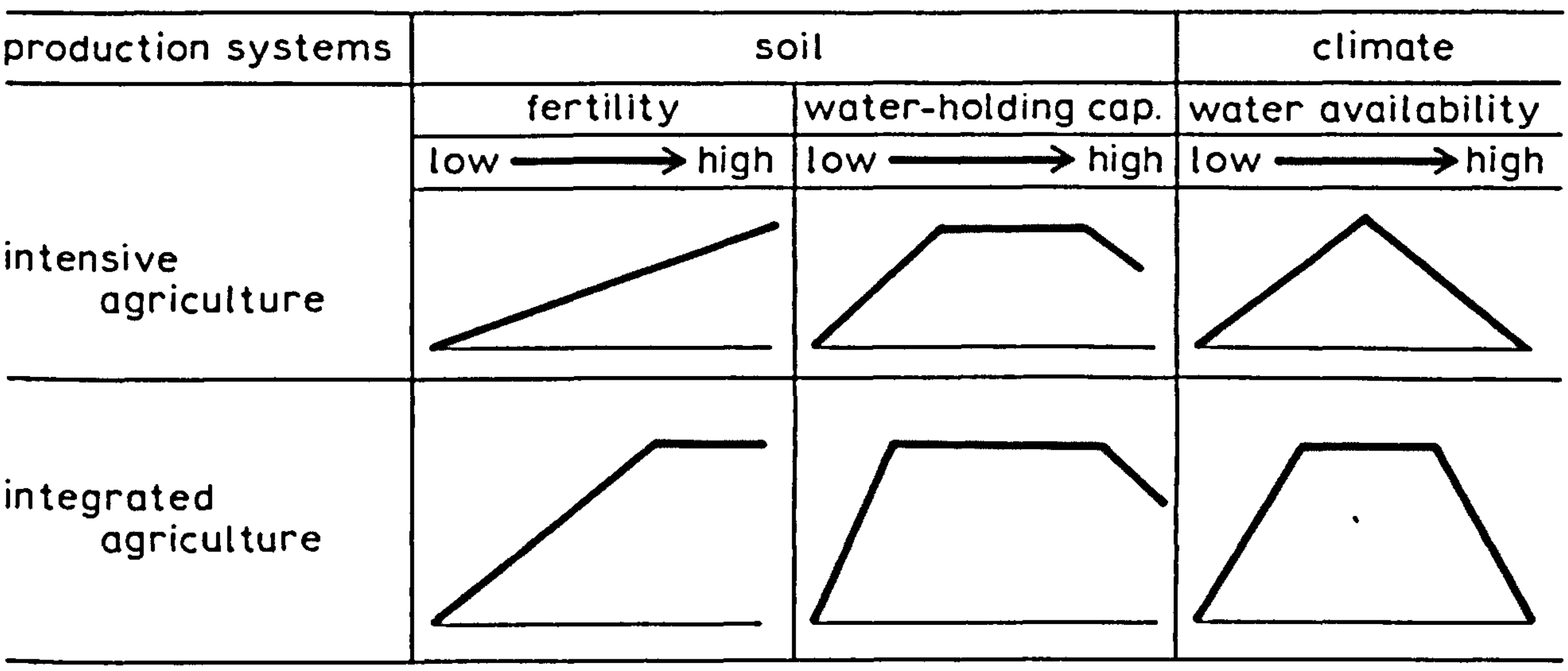

Figure 89. The production efficiency of intensive agriculture in relation to the potential of the environment, compared with such a relation for integrated agriculture.

suggest that the decline in area of this crop is due to its low yield and the low price of cotton cake. The low yield is rather self-evident. Generally, recommending cultivation of legumes is still not automatically linked to recommending the use of P fertilizers, despite ample evidence of P deficiency and its negative consequences for the production of legumes (Penning de Vries & Djitèye, 1982). In addition, labour productivity is low and there is a shortage of labour in parts of the cropping season (Brossier & Jager, 1984). A yield of 1000 kg ha^{-1} dry matter of cowpea fodder is then unacceptable; using P it can be several times higher!

Experience in monsoonal northern Australia suggests that legumes alone could probably improve the natural rangelands in southern Mali, but with insurmountable management problems. Application of P fertilizers could partly alleviate these problems and might increase the production of animal protein 5-fold (Breman & Traoré, 1987).

16.4 Concluding remarks

I hope that the suggestions put forward in this chapter wil provoke de Wit and his school to extend their models for various production situations (potential production, production with limited water supply, and production with limited supply of water and nutrients) by introducing forms of integrated agriculture at the various levels. Such models would be useful tools in agro-ecological research to identify appropriate innovations with less concave relations than the curve of Figure 87, without unnecessary trial and error.

Development of integrated agricultural production systems could lead to improved prospects for marginal areas. However, populated areas with conditions characteristic of those to the left of the break-even point in Figure 87, will remain. Only social measures can guarantee sustainability of life there. Once overpopulation is a reality in such areas (Figure 86B), social measures are to be preferred above giving 'stones for bread', by condemning cash crops and advocating natural alternatives only.

Situations exist where interdependence is preferable above independence. It may be a prerequisite for an increased independence of the country as a whole that the Sahelian region remains dependent on the savannah zone, and it may be a prerequisite that farm sizes increase in the latter zone. Charity begins at home.

In this chapter I have attempted to demonstrate the usefulness of systems analysis in development cooperation. If I have succeeded, this implies that the methodology has to be taught in developing countries that may want to decide unilaterally the position of the break-even line (Figure 87) and its dynamics. Hopefully, an increasing number of scientists will follow this line of thought and use the tools initiated and strongly advocated by de Wit, joining me in the song:

'O, I takes the gospel, when ever it's possible but with a grain of salt'.

16.5 References

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