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INTEGRATING SMALL SCALE IRRIGATION DEVELOPMENT WITH THE EXISTING AGRICULTURAL SYSTEM: A CASE STUDY OF SMALL HOLDER SWAMP RICE SCHEMES IN SIERRA LEONE

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INTEGRATING SMALL-SCALE IRRIGATION DEVELOPMENT WITH THE EXISTING AGRICULTURAL SYSTEM: A CASE STUDY OF SMALLHOLDER SWAMP RICE SCHEMES IN SIERRA LEONE[1]

Karlheinz Knickel[2]

1. BACKGROUND OF THE RESEARCH PROJECT

1.1 Bridging the Gap Between Development Theory and Project Implementation

Effective agricultural development programmes are those that build on the strengths of existing farming systems and, at the same time, take due account of the specific natural, socio-cultural, institutional and economic environments.

Correspondingly, development concepts need to be based on:

- a thorough understanding of existing and, under the given conditions, efficient farming patterns;
- an appreciation of farmers' needs, decision-making environment, indigenous resources, capabilities, experience and social structure;
- the identification of suitable, ecologically stable, socially acceptable and economically attractive development opportunities - farmers are responsive to suitable opportunities;

1 This paper is a synopsis of a PhD thesis submitted to the Cranfield Institute of Technology, Silsoe College, UK. For the complete research report reference is made to Knickel, Karlheinz: Farming Systems Development - Smallholder Swamp Rice Schemes in Sierra Leone. Studien zur Integrierten Ländlichen Entwicklung, Band 27, Verlag Weltarchiv Hamburg (ISBN 3-87895-359-3).

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- a socio-economic and institutional rural environment conducive to the adoption of technology;

- an implementation strategy which allows farmers to get to grips with the new technology or practices and to adapt them to their specific conditions of resources, risk and constraints.

The research presented here tries to apply this philosophy to the problem of effective implementation of small scale irrigation development: 75% of the 250 million hectares (ha) irrigated throughout the world can be referred to as peasant irrigation schemes, and expansion of small scale irrigation will be one of the most important issues in the coming years.

The possibility of conducting this research arose following a two year assignment by the author with the Food and Agriculture Organisation of the United Nations (FAO) in Sierra Leone, West Africa. The work included a wide range of field studies. After a preliminary analysis of the field data in Sierra Leone, a more thorough analysis was carried out at Cranfield Institute of Technology, Silsoe College, UK.

Besides deriving specific recommendations for swamp rice development in Sierra Leone, the research aimed to contribute to development of ex-ante appraisal techniques for the small scale irrigation sector. The central element of the research could be described as a systems approach to farm analysis, planning and development. Most of the studies carried out focus on the traditional agricultural system, including the economic, social and organisational aspects at the individual farm level. Attributes of the natural, socio-cultural, economic and institutional environment are taken into consideration as they affect farmers' decision-making.

1.2 Swamp Rice Development in Sierra Leone

The main emphasis in current agricultural development policies in Sierra Leone is on promoting more productive alternatives to the rotational bush fallow system ('Shifting Cultivation'). Although this system is highly efficient in terms of resource use under conditions of low population densities, its productivity, measured as rice yield, is not sufficient to satisfy urban food demand in the long term. In addition, shortening fallow periods, resulting from more intensive use of the land, are leading to incomplete regeneration of soil fertility. This has serious consequences for the sustainability of the entire system.

At the same time, Sierra Leone has tremendous potential for irrigated rice production. It is estimated that the potential Inland Valley Swamp (IVS) area in the country is not less than 360,000 ha. The possible benefits to be derived from irrigation development appear substantial: firstly, decreased dependence on rainfed agriculture and the ecologically fragile upland soils; secondly, the potential for increased cropping intensities; and thirdly, reduced risk of crop failure due to inadequate or erratic rainfall. The climate is characterised by a distinct dry season between December and April. Although average rainfall far exceeds evapotranspiration, soil moisture deficits restrict cropping during the dry season severely. Heavy rains during the wet season, in contrast, cause erosion, extensive leaching of nutrients and the flooding of lowlands. Humidity is high throughout the year.

The situation described above applies to other West African countries of the moist subhumid/ humid zone (Nigeria, Benin, Ghana, Togo, Cote D'lvoire, Liberia, Guinea).

1.3 The Traditional Farming Systems

The structure of the agricultural sector of Sierra Leone is characterised by the predominance of the smallholder. Seventy-four percent of the farms were under 2 ha in 1985.

The central element of traditional farming systems is the mixed upland farm where rice is intercropped with a large number of other crops. The upland farm provides the farm family with a wide variety of food crops and has, as a result, priority over swamp cultivation. On 20-30% of farms it is complemented by the extensive cultivation of a smaller area of swamp land (traditional paddy or lowland rice cultivation). The swamps in the area are generally fertile, but flooded in the rainy season.

A tendency towards shortening fallow periods and the farmer's desire to generate a cash income make changes necessary. Maize and groundnut farms are becoming increasingly popular and some farmers are producing considerable marketable surpluses by using their traditional methods of farming more effectively. Most of the farms studied can be considered to be in a period of transition from subsistence to more commercial farming (Knickel, 1986).

1.4 Reasons for Introducing Improved Water Management

Alternatives to irrigation development have not had the desired impact or appear less appropriate:

- The scope for improving the productivity of the mixed upland system in terms of rice production is clearly limited. Tree crops and alley cropping are ecologically more stabile on the fragile upland soils and should therefore replace upland rice cultivation in the long term.

- The use of large scale mechanised power in rice farming has not only proved too expensive for. the country but also unmanageable. Opportunities for farm-level or small-scale mechanisation are limited.

Swamp rice cultivation is already an important element of the existing farming system - complementary to mixed upland farming. Traditionally, however, water control is not practised, resulting in relatively low yields, limited productivity and limited development opportunities. There is therefore tremendous scope for introducing improved water management. The main components of such improvement are:

- Adjusting soil moisture and flooding levels to those required for optimum and uniform crop growth, including control of flood water discharges and thus damage to crops;

- Reducing the effects of the pronounced seasonal changes of rainfall and bringing the advantages of dry season cropping to bear (e.g decrease in crop pests and diseases, more efficient crop growth, drying of crops less difficult);

- Allowing more effective use of mineral fertiliser application and modern rice varieties, improving the uptake of soil nutrients, and reducing iron toxicity through drainage.

Consequently, there is considerable scope for increasing cropping intensity by introducing diverse dry season cropping and by improving the use of residual moisture. The introduction of water management practices can be seen as a major step towards multiple cropping systems. Farmers would, as a result, have more choice in terms of timing and cropping pattern, allowing a more effective utilisation of family labour. Overall, irrigation development would introduce flexibility into existing farming systems and increase the

stability of upland and swamp land use patterns.

1.5 Some Organisational and Technical Aspects

Most swamp rice development programmes in Sierra Leone are part of larger integrated agricultural or rural development projects. Usually, swamp amelioration involves complete clearing and the construction of water control facilities, drainage channels, gravity flow irrigation systems, land levelling and bunding. After the physical improvement of land, farmers are expected to intensify crop production, aiming for both yield increases and multiple cropping patterns. Fertiliser application and the use of shorter duration varieties are the key elements of the more intensive cropping system. Emphasis in most programmes is given to maximum farmer participation and farmer control in terms of: (a) size and management of the scheme, and (b) labour and capital input.

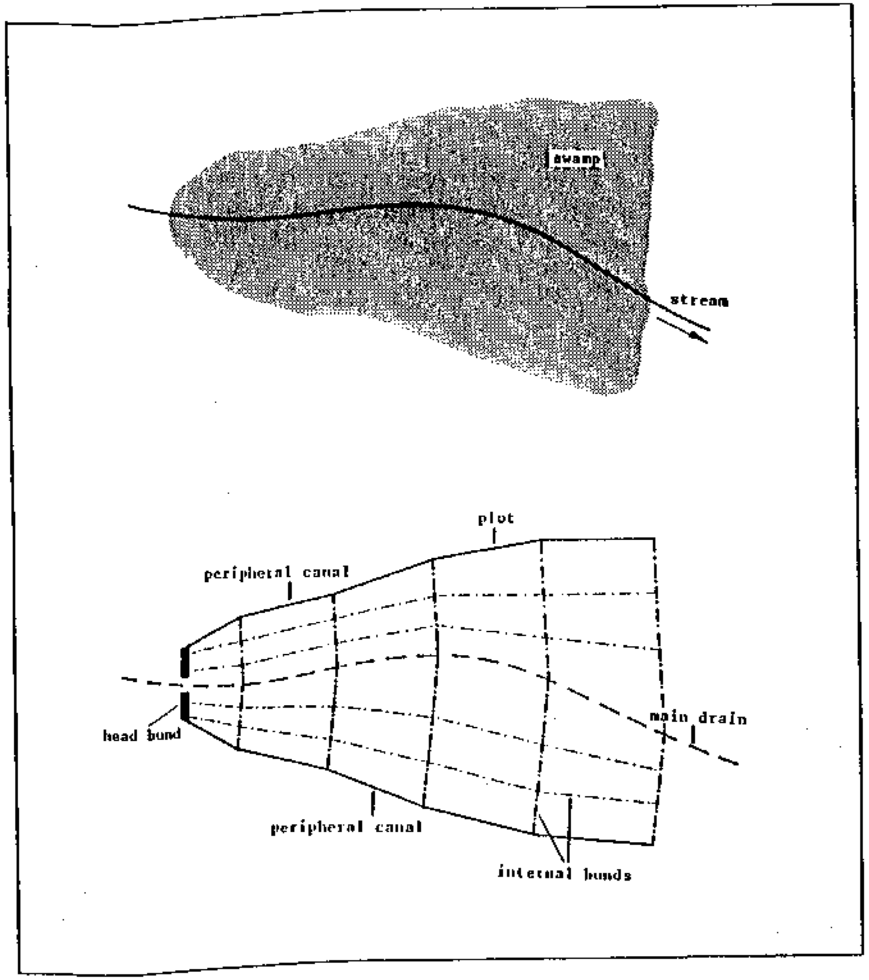
Taking the traditional system as a starting point, swamp development can be subdivided on the basis of degree of water control:

(0) Traditional (uncontrolled water; cropping pattern and rice variety are chosen according to given soil and water conditions)
(1) Better use of residual moisture
(2) Bunding, land levelling
(3) Flood control measures
(4) Drainage
(5) Gravity flow irrigation system (in combination with [l]-[4])

Figure 1 shows a typical layout for a gravity flow surface irrigation system using basins (FAO, 1985).

In Sierra Leone emphasis in swamp development has for some time been on the 'small scale' approach, i.e on "schemes which are under local responsibility, controlled and operated by the local people in response to their felt needs" (Underhill, 1984). The inherent, potential advantages of small scale irrigation development are the low-capital input, the cost effectiveness and the mobilisation of local resources, the sustainability of developments, and finally, the positive effect on rural development. Schemes aimed directly at the farmer seem to be a particularly valuable alternative to large scale, centrally planned schemes in difficult economical environments, and to developments in countries where there is little experience with irrigated farming.

Figure 1: Typical Layout for a Gravity Flow Surface Irrigation System Using Basins (FAO, 1985)



In spite of small scale programmes being a valid instrument of development policy, some weaknesses are inextricably interwoven with the potential strengths: farmers are eminently sensitive in rejecting new technologies, if these don't match their specific opportunities or goals. The problem is aggravated if technologies are too complex to allow farmers to experiment with them, without incurring considerable risks or substantial resource reallocation. Participation and initiative of the target groups, however, is the single most important factor in terms of uptake of technology, continued operation, management and maintenance.

1.6 The Experience

The technical feasibility and the potential of irrigated rice production can be shown in small pilot programmes. An extension of the technology on a wider scale has, however, generally not had the desired impact. To date, farmers are reluctant to adopt the new technology. The diffusion of improved water management practices, in particular, is minimal. Less than 60% of the supposedly developed swamp land in the study area was actually under crop production and less than 10% under double cropping (Knickel, 1985). A large scale yield survey indicated that in 78% of all swamps with drainage and irrigation structures the rather modest minimum yield required to offset total production costs (1.9 t/ha) was not reached (Knickel, 1986).

The major problems seemed to be (in random order):

- The fragmented and diverse nature of the irrigation schemes result in non-uniformity in their physical, social and economic characteristics.

- On the technical side, there have been design, lay-out and construction deficiencies which are compounded due to lack of proper maintenance and operational shortcomings. Farmers do not utilise structures to control water. Standards of watercourse operation and maintenance, and in-field irrigation and levelling, are often too low.

- Lack of a tradition in the discipline of irrigated agriculture, and of knowledge of the benefits of improved rice varieties and fertiliser is exacerbated by the inability of the greater proportion of farmers to buy these inputs.

- Marketing is inadequately organised and seems not to provide incentives to produce more.

- Small farmers may well prefer current low levels of income if higher levels are associated with additional risk. Present IVS development appears to reflect government policy objectives and meeting targets of agricultural development projects, rather than a positive decision by farmers for involvement.

- Many swamps have been partly developed and then abandoned, or farmed only for a few years and allowed to revert. Only a few swamps have been continuously farmed for lengthy periods.

- Farm inputs and services, such as supplies, credit, advice, and marketing, appear insufficient to support more commercial farming. Inadequate in-service training, limited staff mobility and lack of incentives reduce the capacity of the extension system.

- Land tenure problems seem to discourage investment in swamp amelioration in some cases.

If we look more carefully at the above list, some of the points appear to be symptoms and others causes. The research project attempted to ascertain the true underlying causes and to find the most appropriate manner in which to develop IVS crop production within the existing traditional farming system. Concurrently, an attempt was made to identify practical ways of integrating farming systems research with production-oriented projects.

2. CONCEPTUAL FRAMEWORK, DATA COLLECTION AND ANALYSIS

2.1 Conceptual Framework

The unique possibility of linking research and development during the field work phase enabled close coordination of the diagnosis, implementation and monitoring stages of the project. The research approach applied was essentially two-pronged: firstly, studying the existing agricultural system, and secondly, defining the developed swamp system in terms of input-output relationships. Finally, both systems were combined by means of (i) on-farm testing and farm case studies, and (ii) mathematical programming analysis and partial budgeting.

The first stage provided an understanding of the existing traditional farming system and identified inherent development opportunities: Why do farmers farm the way they do? What are the advantages of traditional cropping systems, and are there possibilities for increasing their productivity? What are the factors which determine "farmers' response to new technological opportunities"? (Tiffen, 1987).

The second stage defined the new technology under consideration in terms of input-output patterns and resource demand. This was linked to testing the compatibility of the new technology with the existing farming system, particularly with regard to critically limiting factors and to determination of the demand for external inputs and adjustments (analysis of the wider agricultural system).

The hypotheses which were tested evaluated alternative levels of technology and alternative time scales of development. These are listed in Sections 3.4 and 3.5.

2.2 Data Collection and Analysis

Weinberg (1975): "If we want to learn anything, we mustn't try to learn everything."

Each study or survey was based on earlier studies to provide continuity and to ensure that only relevant and adequately precise data were collected. The farm case studies and sample surveys conducted are summarised in Annex 1. In order to mitigate the limitations of a two year study, swamp rice development was examined at various stages of the development process on different farms. Technical coverage was restricted to core information.

A combination of statistical, economic and modelling approaches were used for data analysis. Relatively simple models have the advantage of being relatively easy to use, and of permitting the chain of causality between assumptions and model output to be more readily understood. Partial budgeting was used to assess the financial viability and comparative profitability of irrigated rice production. Different time periods for appraisal were considered by means of discounted cash flow analysis, to reflect the planning horizon in farmer' decision-making.

Treating swamp rice development more rigorously as a resource allocation problem requires linear programming (LP) analysis or similar methods for optimising the complete farming system. Using LP, different farm resource base situations were tested as they affect the compatibility of the new technology with the traditional rainfed systems: key resources were identified, and the effect on farm incomes and on the production of marketable rice surplus was assessed. Improved crop vectors with reduced levels of cash inputs were included in the matrix in order to allow a closer coordination of farm plans with given resource situations.

3. CORRELATION OF RESULTS

3.1 Agricultural Support Services and Socio-Economic Environment

Technological change requires both the organisational structures necessary for diffusion and adoption, and the people's participation. Disincentives for rice producers extend well beyond the pricing mechanism. Farmers may refuse to adopt new practices because external factors, such as inadequate input supply and advisory services or disincentive marketing policies discourage them. Agricultural support services need to be reliable and predictable. They need to be coordinated with the requirements of new technologies.

Advisory services The vast majority of farmers in the study area perceived the quality and capacity of the existing agricultural services as inadequate. The group of farmers particularly affected were those primarily concerned with more intensive swamp cultivation. Effective advisory services are especially required if the intensive rice system is to be implemented as a package within a short time frame. Longer term development, in contrast, is less dependent on the capacity of the extension system.

Farm input supply A characteristic of mixed upland and traditional swamp farming is that both systems do not depend on external production inputs. Immunity from the effects of unreliable or generally inadequate input availability is an important consideration in farmers' decision-making, and confidence in supply lines is a precondition to farmers' willingness to adopt more input-intensive production systems.

Producer prices Pricing of agricultural produce in relation to the price of farm inputs is a key factor in determining the optimum intensity of cultivation. In the case of Sierra Leone, recent pricing policies justify

investment in swamp rice development. Farmers appear generally content with producer prices for rice.

Marketing facilities Wide producer price fluctuations for rice are largely due to the limitations of the existing marketing facilities (storage, transport, market transparency), and the fact that most farmers sell their rice at harvesting time or soon after.

Credit Financial assistance can easily undermine self-reliance and motivation if not carefully attuned to farmers own resources. It is not necessary if swamp rice development strategies are conceived in such a way that the improved cropping system evolves as a result of a series of discrete changes to the existing system. The package approach, in contrast, competes heavily for resources, which is also expressed in the need to hire additional labour.

Land tenure Some analysts argue that the communal land tenure system is a disincentive to investment in land amelioration. Although problems with respect to land tenure were more common among swamp farmers, this did not generally seem to be a primary constraint to an intensification of swamp cultivation. In cases where land tenure is a problem, the possibility of long-term lease arrangements could be explored with the local authorities as custodian.

3.2 Farmers' Objectives and Decision-Making

Subsistence Mixed upland farming is the cropping system which provides farmers and their families with most of the food crops they need. To secure family food requirements is farmers most dominant objective. Commercial farming is increasing in importance, but is still secondary to subsistence farming.

Commercial orientation Sole cropped upland maize is more orientated towards provision of a cash income for farm families. Fertilizer is required and most of the maize produced is for sale. The fact that maize farms are becoming increasingly popular in the study area, clearly indicates that farmers are becoming more inclined to produce for the market. For an estimated 20-30% of the farmers, production for the market seemed to be a primary objective.

Minimising risk Combining mixed upland with swamp farming can be seen as a measure to minimise the risk of inadequate or erratic rainfall which would result in insufficient rice production. The mixed upland system in itself is a risk aversion strategy: spreading risk by cultivating a range of crops in a mixed stand.

Efficient utilisation of available resources Resources are allocated to optimise benefits at the whole-farm level. One of the main concerns of the farmers studied was making the most effective use of available family labour by coordinating upland and swamp farming activities accordingly.

3.3 <u>The Integration of Upland and Lowland Cropping Systems</u>

Modelling traditional farms showed how well upland and lowland cropping systems are attuned to each other and to the given resource base. The main advantages of combining mixed upland cultivation with low-input swamp farming are:

- Climatic uncertainties and risk are minimised by making use of the two ecologically very different environments.

- Family labour input is more evenly distributed over the year by phasing upland and lowland crop calendars (Figure 2). In addition, all available land types are utilised, allowing farmers a lower intensity of land use.

- The greater flexibility farmers have, as a result of combining upland and lowland cropping systems, allows them to respond more easily to changing market and climatic conditions.

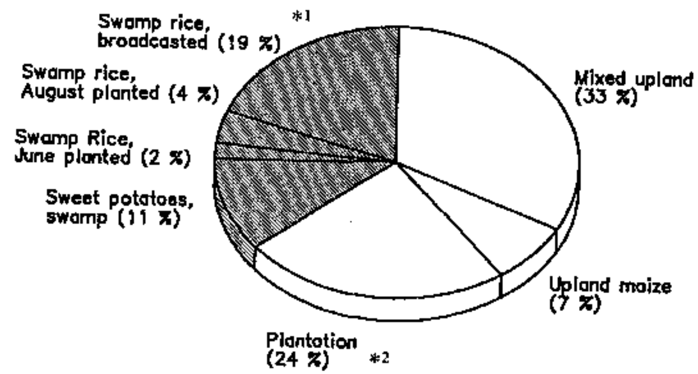
Empirical data on production and income was supported by LP analysis: farms based solely on swamp or solely on rainfed upland cultivation were less profitable than farms which combine both systems. Swamp-only farms achieved approximately half the potential increase in total crop net revenue possible from irrigated farming.

There are two main conclusions from this:

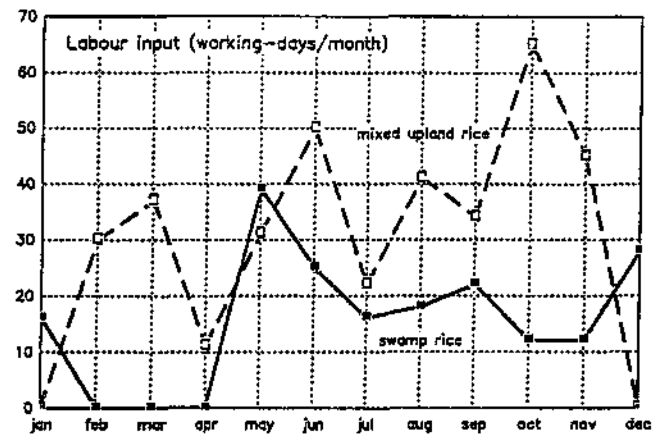
(a) Considering the limited range of available resources and their already efficient allocation in existing traditional farming systems, it is doubtful whether there is much scope for improving resource use efficiency without introducing some form of new technology.

Figure 2: Integration of Upland and Lowland Cropping Systems in the Traditional Farming System - an Analysis of the Phasing of Labour Input

(a) Traditional mixed farming system (farm plan derived from LP-analysis)



(b) Corresponding phasing of labour input (based on the above farm plan)



*1 % refers to "percentage of total farm land farmed by one household"
*2 Coffee and some citrus in upland areas; generally overaged, poorly maintained with marginal yields

Source: Knickel (1988)

(b) Compatibility between the main components of the existing farming system and the improved swamp rice technology is a fundamental issue. Less outside labour needs to be hired if sharp peaks in the demand for a workforce are avoided. In addition, the cost of fixed inputs, such as developed land, is lowered by improving the use of variable resources.

3.4 Level of Technology

Generally, a flexible approach towards swamp amelioration is necessary to allow for the heterogeneity of site conditions. Shortcomings in design, lay-out and construction create major operational problems (Weatherhead, 1984). A considerable proportion of technically sound water control systems are not used properly because the farmers have never been sufficiently introduced to the basic principles of irrigation water management.

With respect to the technical appropriateness of swamp development, more applied research seems to be needed on such issues as linking a specific set of soil-water parameters with the most suitable amelioration pattern. This work must consider the pronounced seasonality of rainfall, the fluctuation in stream flows, the water availability during the dry season and, as a result, the engineering design required. The problem of choosing an appropriate level of technology is discussed below by considering five different hypotheses.

Hypothesis 1: "Farms which include an 'intensive swamp rice production' enterprise are superior to traditional farming systems in terms of total crop net return and total rice production per farm and year."

Rice yields in traditional swamp cultivation range from below 1 t/ha to above 4 t/ha, with the highest 10% of yields averaging 3.6 t/ha. There is, therefore, tremendous scope for increasing swamp rice yields with comparatively low capital input. Some 'better farmer practices' could be identified. Experimental yields in ameliorated swamps were commonly in the range 3-5 t/ha. Rice yields obtained in farmers' improved swamp cultivation were on average, however, not significantly higher than the yields obtained in traditional swamps.

In spite of this, a small number of farmers showed that substantial increases in rice production and a diversification of cropping patterns following swamp development are possible and linked to higher farm incomes. LP analysis

indicates that total crop net revenues, which constitute nearly three quarters of farm income, can be increased by 18% through irrigation development in seasonal swamp areas. In areas where swamps have perennial surface water the corresponding increase is 32%. With regard to partial development of swamps, net revenues could be raised by 17% in seasonal and by 26% in perennial swamps. The figures given are based on yield levels of 2-2.5 t/ha. They apply to technically sound irrigation development and depend on a full utilisation of the given production potential (Table 1).

Table 1: Linear Programming Solutions for Improved Swamp Systems

Water regime:	SEASONAL			PERENNIAL		
Degree of water control:	control	partially developed	irrigated	control	partially developed	irrigated
Net revenue (USD)	645,17	753,10	763,99	704,54	880,26	929,82
Increase (%)	.	16,7	1,4	.	24,9	5,6
Farm composition (ha/farm):						
upland:						
maize	0,7	0,1	-	0,3	0,1	-
plantation	1,0	1,0	1,0	1,0	1,0	1,0
groundnuts	-	0,4	0,5	-	0,4	0,1
mixed	1,6	1,1	0,8	1,4	1,1	0,7
swamp (rainy season):						
sweet potatoes	-	-	-	0,44	-	-
traditional rice	0,24	-	-	0,99	-	-
improved rice	-	0,9	1,2	-	0,9	1,5
swamp (dry season):						
vegetables	-	-	0,1	-	-	0,7
groundnuts	-	0,3	-	-	1,0	-
Credit required (USD):						
	-	22,64	30,63	-	22,87	39,48
Rice production (marketable surplus (above 2205 kg/year):						
kg/year	82	1226	1833	671	1254	2586
Source: KNICKEL (1988)						

It could be argued that economically optimal plans (as derived from the LP analysis) will not be achieved in reality and that, for this reason, predicted increases of 20-30% in total crop net revenue are not sufficient. Two aspects, however, ought to be considered. Firstly, producer prices for rice fluctuate widely, reaching their peak between June and August. Irrigation development would give farmers the flexibility to produce rice ready for harvesting at times of peak price. Secondly, the flexibility farmers ultimately have in fine-tuning improved farming systems, will tend to increase whole-farm productivity rather than decrease it.

Considering total annual rice production per farm and the production of marketable rice surplus (defined as rice production above 2.2 t/year), LP analysis indicates that improved farm systems are superior to traditional systems. Irrigation development in perennial swamps would raise total annual rice production per farm by 67%, which corresponds to an absolute surplus of about 2.6 t/yr farm. Overall, there appears to be sufficient evidence to support Hypothesis 1.

Hypothesis 2: "Intensive swamp rice production is compatible with farmers' overall objectives - considering needs, resources, alternatives and constraints."

Farmers tend to shift to more intensive lowland farming where rainfed upland farming is becoming more difficult. Examples are the drier northern and the more densely populated coastal areas. The decision to shift emphasis from mixed upland to swamp farming, where mixed upland farming is becoming less productive, or equally, where swamp farming is becoming more productive, can also be simulated by LP.

In terms of efficient use of scarce resources, an intensification of land use is not an obvious development in light of the relative abundancy of land. Nevertheless there appear to be three important aspects justifying irrigation development. Firstly, the efficiency of labour use will be increased. Secondly, returns to labour are generally higher in irrigated crop activities than in traditional activities. Thirdly, the opportunity cost of family labour during the dry season, when the major engineering works would be carried out, is low. The labour peaks in the traditional system are May-August (planting) and October-December (harvesting).

Farmers' aims to remain relatively independent of external inputs and to minimise capital input also seem consistent with - at least a stepwise - intensification of swamp rice production. External inputs into small scale swamp amelioration are minimal, the main inputs are labour and local materials. Nevertheless, more emphasis should still be given to reduce the need for external inputs after swamp amelioration has been completed. Crop rotations with leguminous crops, for example, could reduce the need for mineral fertilisers and would at the same time widen the variety of crops produced (considering subsistence needs and food crop production).

The positive effects of intensification of swamp rice production on farm income and rice production levels are obviously consistent with farmers' objectives. All in all, Hypothesis 2 is supported by the findings of this study, particularly if the points made in Section 1.4 are also taken into account.

Hypothesis 3: "Intensive swamp rice production can be integrated with the traditional mixed upland farming system with respect to the family labour economy."

Whole-farm resource use and specifically the availability and allocation of family labour are central issues in the traditional farm system. Traditional extensive and 'late planted' - or alternatively, broadcasted - swamp rice fits well with the mixed upland system (Figure 2).

Interviews among farmers concerned with improved swamp cultivation indicated that the availability of family labour and cost and availability of hired labour are limiting to the cropping intensity and cultivated hectarage. Optimal farm plans obtained from the LP analysis show that an intensification of dry season crop production in swamps would lead to relatively even labour profiles and good utilisation of available family labour. This would largely be achieved by coordinating the crop calendar in improved swamp cultivation with the mixed upland calendar. Coordinating crop calendars in turn implies that agronomic recommendations take the whole-farm labour profile into account. Choosing an appropriate planting method is an obvious example: transplanted rice requires more labour for crop establishment but less for weeding. Wet seeding in improved swamp systems and the broadcasting of rice in traditional systems, in contrast, are characterised by the opposite pattern of labour use. Both direct seeding methods have advantages as long as swamp farming is to be combined with mixed upland farming. Direct seeding enables farmers to establish a lowland rice crop before the planting of upland farms. Yield losses due to late transplanting (i.e after planting of upland farms had been completed) are thus avoided. Similar considerations apply to choosing an appropriate weed control method.

Overall, it must be concluded that intensive swamp rice production can be integrated with the mixed upland system provided that agronomic recommendations and the planning of crop rotations take the whole-farm resource use pattern into account. Hypothesis 3 is therefore supported.

Hypothesis 4: "In seasonal swamp areas partial water control systems are superior to traditional swamp cultivation in terms of total crop net return and total annual rice production per farm."

The results of the LP analysis indicate that partial development of swamps with seasonal surface water availability is, in financial terms, worthwhile. Total crop net revenue would increase by 17%, and marketable rice surplus from nearly zero in the traditional system to more than 1.2 t per farm and year (Table 1). Hypothesis 4 is therefore supported.

Hypothesis 5: "In seasonal swamp areas partial water control systems are superior to complete water control systems in terms of costs and benefits."

Irrigation development is most appropriate for swamps with perennial surface water, allowing year-round cropping without the need to pump or store water. In perennial swamps, irrigation development adds another 6% to the increase achieved with partial development, giving an overall 32% increase in total crop net revenue (Table 1).

Most of the increase in total crop net revenue and marketable rice surplus per farm in seasonal swamps is, in contrast, already achieved with partial development. Irrigation development would, on average, add only another 1% increase on top of that, which again on average, does not justify additional costs. Hypothesis 5 is therefore supported.

Where other factors are particularly favourable (e.g farmers' interest in multiple cropping systems, experience with partial water control, other agro-ecological factors), irrigation development could still be recommended.

3.5 Time Scale of Development

As important as the right type of technology is an appropriate strategy for its introduction. Swamp amelioration means investing limited resources into

a production system from which substantial benefits accrue only from year three to four onwards. A comparison with the traditional swamp rice systems shows that incremental benefits are less than incremental costs during the first three years (i.e during the development phase). Farmers' time horizon thus plays an important role in deciding on adoption or non-adoption of the improved rice production system.

In the case of implementing the system fully within the first year, net benefits are already substantial in year two. One major disadvantage of this approach is, however, the relatively high take-off point, i.e specifically the much greater expenditures during year one.

Hypothesis 6: "The introduction of 'intensive swamp rice production' as a package is feasible from a farm management point of view and in financial terms worthwhile."

Production packages have been developed to capture the synergistic effects between several components. A typical example is the swamp rice package: water control - fertiliser application - improved rice variety. One dilemma with technology packages is that they soon become too complex, too risky or too demanding in terms of capital investment and managerial capabilities. The adoption of the complete irrigated rice cultivation package would require major or complete change to the existing farming system. In optimal farm plans, the mixed upland rice area is reduced by nearly 40% in seasonal swamp areas and by 50% in perennial swamp areas (Table 1). Although this is in financial terms an attractive long-term goal, the changes required do not seem feasible within one or two years.

Initial resource requirements To implement the irrigated rice system completely within one year, available family labour during the main development period February-April would, on average, only be sufficient for about 0.25 ha per farm household. For larger areas labour input into development would have to be hired which is associated with additional costs and the need for credit.

Experience Characteristic of the extensive nature of traditional swamp rice cultivation is that comparatively labour intensive water control practices are generally not used. Farmers have, as a consequence, no background in irrigation to build upon. In fact, the traditional crop management concept is totally different (Knickel, 1986, 1988).

Most farmers who actually completed swamp amelioration, had not altered cropping patterns in line with irrigation possibilities. Differences in cropping pattern between improved and traditional swamp farmers were, apart from the use of improved rice varieties, marginal. Particularly critical practices with respect to the effectiveness of improved rice systems were the late planting and inadequate levels of mineral fertiliser application or, in more general terms, the problem of soil fertility management. Until now farmers have relied almost exclusively on the rotational fallow system to sustain soil fertility, in upland as well as in swamp farming. Multiple cropping is hardly practised.

Complexity Swamp rice development requires a wide range of changes. The innovation comprises engineering works, irrigation water management, different agronomic practices and substantial financial management - specifically, investment in land improvement, purchase of production inputs and marketing of produce.

The improved cropping system is too complex to be learned within a short time. It is too different from traditional production systems. Farmers do not have the essential agronomic foundation and hydrology skills. They lack knowledge of the practices needed to fully utilise the potential.

Advisory services and production inputs The capacity of advisory services appears insufficient to sustain the relatively high level of technology aimed for: long-term agricultural investment and environmental control (i.e irrigation water management and fertiliser application) are fundamentally different managerial concepts which would require a very strong extension system.

Risk Considering the points made above the new technology probably appears too risky to farmers, although it would ultimately reduce risk and uncertainty.

Financial The most important reasons for farmers' reluctance to adopt the new technology are not economic. Breakeven yields are relatively low, 1.7 t/ha for irrigated and 1.5-1.6 t/ha for partially developed swamps. The problem is that potential yields in improved swamp rice cultivation are generally not achieved at present, and that purchased inputs are not effectively transformed into additional crop output. A number of technical and management problems associated with too rapid an introduction of the new rice technology are largely responsible for the relatively low yields.

In summary, the complexity of the innovation, its high initial resource requirements, the lack of experience with irrigated agriculture in the region and the limited capacity of agricultural services exclude the possibility of a package approach towards the intensification of swamp rice systems. The evidence from the research appears sufficient to refute Hypothesis 6.

Similar difficulties with regard to the implementation of complex technology packages are reported by other analysts: Collinson (1980), Norman et al (1985), Barlow et al (1986), Byerlee et al (1986) and CIRAD (1987).

Hypothesis 7: "The introduction of 'intensive swamp rice production' in a stepwise, incremental manner is feasible from a farm management point of view and in financial terms worthwhile."

In response to the problems involved with extending technology packages, various authors have suggested disaggregation of packages into component subsets. These should allow critical interactions to be exploited. Initial steps should be with the components which are relatively compatible with farmers' existing resource allocation. More complex steps will be possible as farm productivity and farmers' confidence in absorbing new technology improves (Byerlee et al, 1982) (Norman et al, 1985).

Analysing the question of time scale of development again, this time in view of an incremental approach, shows that the main problems described above can be at least reduced, if not completely by-passed. In contrast to a package approach, an incremental approach would give farmers time to gradually develop the necessary skills and experience of irrigated farming. This is also in line with two other aspects: firstly, the need to strike a balance between the large loans required for one-off development and the low household incomes (the cash flow pattern for an incremental approach is better suited to the limited financial resource base); secondly, the need to upgrade agricultural support services.

With respect to financial benefits, yield increases obtained with relatively small changes, such as improved agronomic practices or fertiliser application, are considerable. Financial returns to such improvements are, at enterprise level, correspondingly high. The fact that net present value is only slightly higher in the long term for a package approach indicates that the additional resources and extension service capacity required for this are not justifiable.

Changes in agronomic practices should be seen as a means to initiate longer term swamp rice development programmes. When recommending practices which seem favourable at enterprise level, such as early transplanting, impact on overall resource efficiency also needs to be considered.

Sufficient field experience with a more incremental approach towards the intensification of swamp rice cultivation is not available. This research, however, indicates that field-level programmes should generally give more attention to the question of an appropriate time scale of development. Taking the available evidence into account, the conclusion is that Hypothesis 7 is supported.

4. IMPLICATIONS FOR INLAND VALLEY SWAMP *(TVS)* DEVELOPMENT POLICIES

4.1 Integrity of IVS Development Programmes

The problems of development and production need to be separated. Development involves people as well as land and water and must therefore start with the farmer and his or her traditions (Carter et al, reviewing irrigation development in Nigeria, 1983). The studies carried out in the framework of this research project indicate that the same applies to small scale irrigation development policies in Sierra Leone. Farmers need to understand the basics of the improved production system at an early stage because understanding is directly linked with motivation and participation.

There is a need for better institutional coordination and cooperation particularly in the fields of agricultural support services and applied research programmes. Research, extension and the farmer should ideally form a single system, expressed in the link between on-farm testing, monitoring, evaluation, analysis and training. Pilot swamp development programmes simultaneously provide a possibility to test technology under local farmer conditions, to train extension staff, to collect farm level data in key areas, to organise field days and to learn farmers' views. Implementation, monitoring, evaluation and planning should be continually in progress, each influencing the other (Sequential Programme Planning and Implementation, GTZ1984).

The requirements of the new technology need to be coordinated with the capacity and quality of agricultural services. Farmers concerned with more intensive production systems have been facing difficulties with regard to

input supply and insufficient technical guidance. Weatherhead (1984) points out that the engineering knowledge required must remain within the capability of field staff.

Projects should seek target outputs instead of target areas. This would involve more longer term, continuous efforts in already reclaimed swamps and in the field of actual rice production. Carruthers and Upton (1982) point out that new forms of cooperation are needed to sustain irrigation development over longer periods.

4.2 Need for a Long-term Strategy

The process of development must be slow and incremental, with low investment sustained over a long period (Kay et al, 1985). An incremental approach to the extension of the irrigated rice system appears feasible and ought to be tested in pilot programmes. Practical on-farm trials are necessary' in order to enable farmers to appreciate the possible benefits of swamp rice development.

During the first one or two cropping seasons only minor adjustments should be aimed for in order to minimise risk to the farmer and build trust in the programme: farmers need to be introduced to the concept of soil fertility management on continuously cultivated land. Date of planting, plant spacing and density, crop care and the prevention of post-harvest losses are other important fields. Ideally, the production levels achieved and farming practices used by more productive farms should form the basis for production targets and recommended practices that are used by the less productive farms. At regional level, emphasis during the first phase should be given to upgrading agricultural support services, i.e to training, the mobility of extension staff, to input supply and marketing facilities.

After fanners have acquired some experience with more continuous and intensive cultivation patterns in swamps, the need for better water control will become obvious to the farmers themselves. Building on farmers' motivation to improve the system further and on their willingness to shift emphasis gradually away from mixed upland farming towards more intensive swamp cultivation, introduction of simple water management practices should only be a small step. In perennial swamps this would lead to the construction of irrigation structures. Mechanised swamp clearing and possibly land levelling services, the two operations requiring major labour input, could be offered to farmers on semi-commercial or commercial lines.

4.3 Integrating Rainfed Upland with Irrigated Swamp Cultivation

The most profitable and, with respect to the diversity of enterprises, stable farm structure is achieved by integrating rainfed upland with irrigated swamp cultivation. Bush fallow system and irrigation development should not be regarded as mutually exclusive, but should be developed simultaneously in the areas suitable to each. This will allow farmers to shift emphasis gradually from upland farming to more intensive swamp cultivation and gives them the necessary flexibility to experiment with the irrigated rice technology on a smaller, less risky scale: cautious learning is possible, economic vulnerability is minimised, and the capital resources required are marginal.

4.4 Stratifying Recommendations

(a) Swamp amelioration patterns need to be better adjusted to the given agro-ecolpgical and farm resource situation. "Extension advice must recognise that swamp rice is only one element in a sophisticated mixed farming system, allow for the diversity in farms and take more account of individual circumstances" (Weatherhead, 1984). The recommended amelioration pattern ought to reflect:

- *swamp characteristics* water regime over the year, soil type, catchment, flood discharges, topography.
- *farm situation* structure of the existing farm system, given resource base and allocation, management skills, experience, goals, alternative production systems and non-farming activities,
- *environmental factors* natural, institutional, infrastructural and socio-cultural aspects.

(b) More attention should be given to flexible cropping patterns. Crop rotations should include drought tolerant upland crops, as well as rice, in order to utilise available soil moisture and low rainfall during the tail end of the rainy season more effectively.

(c) In areas where perennial swamps are not available, emphasis should be placed on the study of possibilities of creating small reservoirs upstream of the swamp for supplementary irrigation in the dry season. An alternative to reservoirs could be the use of simple devices for lifting irrigation water from shallow wells.

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ANNEX 1

Field Surveys and Case Studies

The following field surveys and case studies were carried out between October 1984 and August 1986 in Moyarnba District, South-Western Region, Sierra Leone. The study area accommodates nearly 20,000 farm holdings, corresponding to about 9% of the country's total. Seven percent of the holders are women.

(1) *Baseline survey* Sample size 100; random sampling; Moyamba District; multiple choice.

(2) *Farmers' perception of alternative rice cropping systems* Sample size 75; stratified random sampling; Moyamba District; 28 options; translated into local language (Mende).

(3) *Extension workers' views on swamp rice development* Sample size 17; all senior and intermediate level extension staff in Moyamba District; open-ended questions.

(4) *Utilisation study of existing developed swamps* Sample size 20; complete survey of swamps developed before 1983; Moyamba District; multiple choice questions.

(5) *Field yield assessment (FYA) 1985/86* Sample size 300 (swamp rice), 30 (mixed upland rice); stratified random sampling; Moyamba District; crop cuttings in farmers' fields; three plots of 10 sq m each per field (i.e per sample); questionnaire on the history of the particular crop stand sampled (17 factors); multiple choice; Subject: To obtain a reliable and comprehensive data base on rice yields and cropping patterns at different levels of technology and at various management levels.

(6) *FYA follow-up survey: 'High' and 'Low' yield groups* Sample size 45 (and 35 in control group); Moyamba District; stratified random sampling (traditional, improved); above 2.3 t/ha 'high', below 1.3 t/ha 'low'; multiple choice questions.

(7) *FA01MANRF Pilot Swamp Development Programme 1985* 16 participating farmers representing the recommendation domain; Moyamba District; Subjects: Implementation of irrigation development at farm-level; labour input records; followed by a crop production programme; all participating farms were included in (5).

(8) *Multiple visit survey (MVS)I Simplified farm accounting (FA)* 10 participating farmers (MVS), including 6 farms where daily records were kept (MVS/FA); Moyamba District; farmers selected as representative or typical; survey extended over one farming calendar year.

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