5 System Model: Nexus between Transport and Rural Development

The previous chapters described the various impacts of a single project conducted to improve the transport in a peripheral region of Tanzania. Each transport intervention had various effects and it was difficult to separate these effects from general changes or to assess the synergetic impacts of combined transport interventions. In this chapter an econometric model is set up in order to assess the nexus between transport interventions and the observed development.

Regional development in Makete can be described as a shift from a subsistence economy towards a market orientation. During this process the increasing production entails growing time requirements for labour and production- and marketing related transport activities. The limited time budget might set restrictions for the further increase of productive activities. On the other hand the rising cash income gives an opportunity to use more non-labour inputs like seeds and fertiliser, which entail a further growth in production. It is difficult to judge the effects of the various interrelations, feedbacks and restrictions. The goal of this chapter is to present a model, which visualises these interrelations by using a systems dynamics approach. The software used was developed by the Michigan Institute of Technology and its most popular applications were the world development scenarios published by the Club of Rome.

The main idea is to simulate the process of a growing market orientation of a predominantly subsistence oriented region over a period of 20 years. The initial situation assumes complete isolation of the region. The scenario technique is used to assess the impacts of various transport investments: footpaths, feeder roads, local tracks, IMT and transport avoiding measures. **The main purpose of the model is to compare the relative effects of these scenarios on regional production, marketing, disposable income and time budget.**

5.1 Basic Features of the Software: Two Examples

The basic feature of the systems dynamics approach is to assess the interrelations and feedback processes between the system elements during a given period. Initially a number of simple equations is set up to define the relationship between the system elements. By calculating these equations step by step for every period of the modelling time (e.g. one year) the systems approach is able to assess the various interrelations and feedbacks of the variables. Even simple equations can result in structures which are so complicated that a mathematical solution is often not possible (FORRESTER 1972 p. 85).

The software works in such a way that first the system relations are graphically visualised and later on the equations are defined. The main graphical ele-

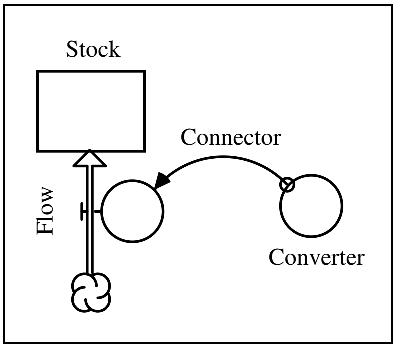
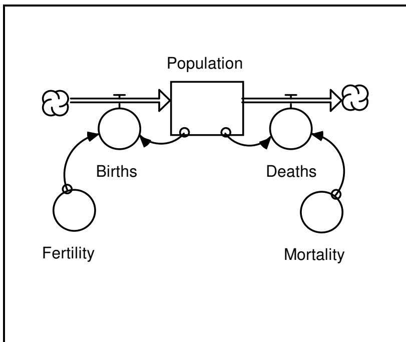


Fig. 5.1-1: Basic elements

ments are stocks and flows, converters and connectors, which are plotted in Fig. 5.1-1. Stocks are reservoirs, which change only if something flows in or out. A flow transfers every period material into or out of the stock. Converters are "catchalls" which convert inputs into outputs. Connectors are used to transfer information from stocks, flows or converters to other converters or flows.

The example of a natural population growth describes a simple feedback process. On the left hand side of Fig. 5.1-2 the small model is visualised, in the middle sction the equations are given and on the right hand the output is plotted. The stock "Population" describes the number of people in a region, which was initially set at 20,000 inhabitants. Every year the new born children (flow "Births") are added and the "Deaths" are subtracted from the number of inhabitants. The number of births and deaths are regulated by the "Fertility" and "Mortality" rates (converters). Every year 5 % of the population give birth to a child and 3 % of the inhabitants die. In the first year the population grows by 400 inhabitants because 1000 children were born and 600 people were dying. The result can be described as an exponential growth of the population at an annual 2 %, which reaches nearly 30,000 inhabitants after 20 years. This example constitutes a **positive feedback loop**, which is a self reinforcing process because a growing stock (population) causes a bigger increase of the flows (births and deaths), which results in a bigger stock in the next period.



Population(t) = Population(t - dt)
+ (Births - Deaths)*dt
INIT Population = 20000
INFLOWS:
Births = Population*(Fertility/100)
OUTFLOWS:
Deaths = Population
*(Mortality/100)
Fertility = 5
Mortality = 3

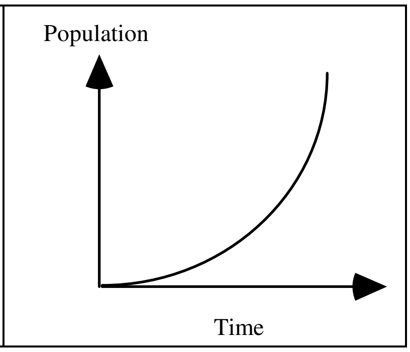
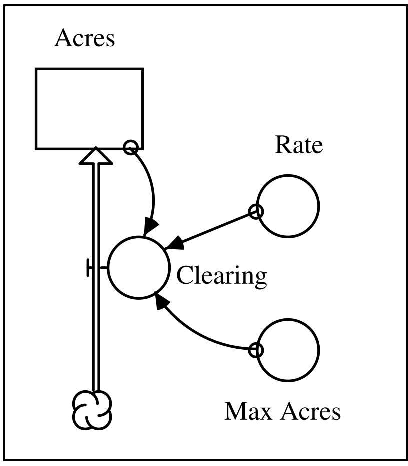


Fig. 5.1-2 Natural population growth (Example 1)

The next example in Fig. 5.1-3 shows the growth of cultivated area during a process of market integration. In the initial period 5 acres are under cultivation. The maximum acreage which one household is able to cultivate is set at 15 acres (converter "Max Acres"). During the development process the farmers will not immediately take the whole 15 acres under cultivation, but the households will clear new land every year at a special "Rate". The model assumes that annually 20 % (converter "Rate") of the difference between maximum and actual acreage are cleared (flow "Clearing"). This implies that every period a smaller acreage is cleared; in the first year 2 acres are taken under cultivation in the last year only 0.03. The curve of the "Acres" shows an asymptotic approximation towards the defined maximum acreage. After 20 years the cultivated area has grown from 5 to 14.9 acres. This process constitutes a **negative feedback loop**, which seeks to maintain conditions in line with target values.




```
Acres(t) = Acres (t -  dt)
          + (Clearing) *  dt
INIT Acres = 5

INFLOWS:
Clearing = (Max Acres - Acres)
            * Rate/100

Max Acres = 15
Rate = 20
```

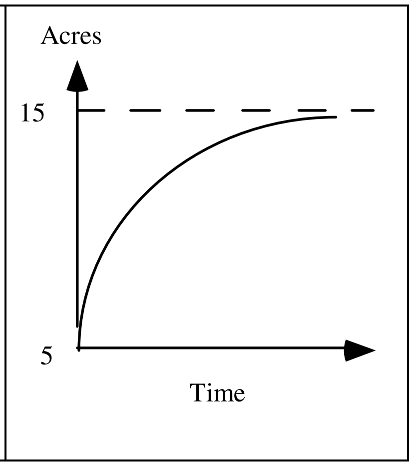


Fig. 5.1-3 Growth of agricultural area (Example 2)

Systems dynamic models combine various positive and negative feedback loops and assess the outcomes of their interactions[1]. As an example a combination of the above described positive and negative feedback loops shall be given: a growing population will clear fallow land until the whole arable land is under cultivation. If the population continues to grow, a decreasing per capita acreage will either lead to out-migration or to decreasing fertility rates due to nutritional deficits; the exponential population growth will turn into an S-shaped curve. This process can be simulated if the negative and the positive feedback loops are combined in one model. For example, the maximum acreage could be defined as function of the population and the fertility rate be dependent on the acreage per capita.

5.2 Description of the Model

The model describes the nexus of production and transport as it was observed in Makete. The main system features are given in Fig. 5.2-1. The agricultural production, which is the salient variable of the system, is determined by the following inputs: labour, cultivated area and amount of fertiliser used[2]. The biggest

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1 For further reading: FORRESTER (1972) and GOODMAN (1974).

2 The production function was estimated in a multiple regression described in Chapter 5.2.3.

share of the products is consumed by the farming households and only a small share is traded on markets. Marketing revenues reduced by the input costs determine the agricultural income of the region. A small positive feedback loop symbolises an income multiplier: a share of the agricultural income will be spent on locally produced consumer goods, which increase the non-agricultural income of other housheolds in the region. The main negative feedback loop is caused by the transport activities, which are determined by the transports necessary for subsistence, crop production and crop marketing. A rising transport burden reduces the disposable time of the time budget. If more time is used for transport activities, less time can be spent for labour in the fields. This feedback loop establishes an equilibrium between the time needs for labour and transport. The number of working hours is rising as long as enough time is disposable. Increasing labour makes the cultivation of more plots possible and leads to a bigger acreage. A positive feedback loop exists between the amount of fertiliser and the income. If the income rises more fertiliser can be purchased in the next period. The model contains several other loops which are of minor importance.

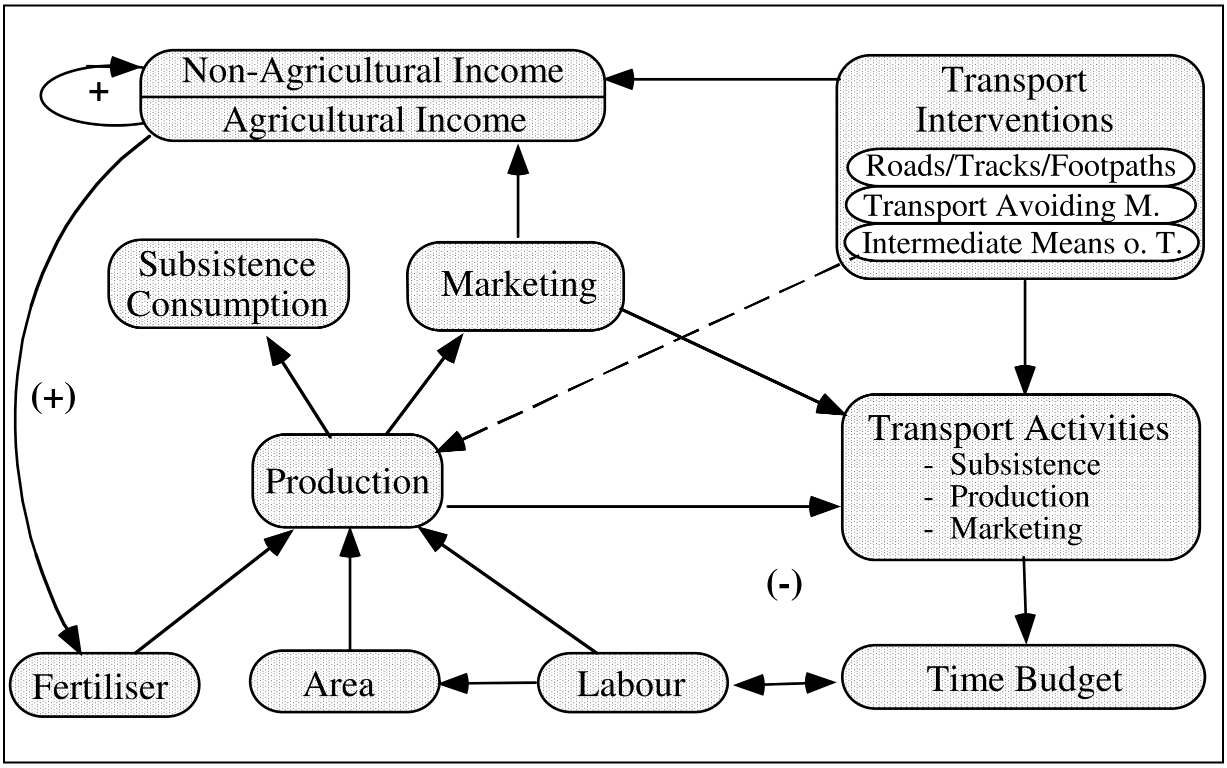

Fig. 5.2-1 Main features of the model

Transport interventions influence the transport patterns of the household and modify the time budget, which leads to a changing production. Some of the interventions have direct impacts on the household's income situation or the agricultural productivity. Five scenarios will be developed to compare the impacts of different changes in the transport system.

5.2.1 Main Assumptions

The following assumptions had to be undertaken in order to establish the model:

(i) At the outset the region is completely isolated from abroad, the economy is basically relying on subsistence agriculture and only a small share of the products is sold in local markets in order to cover the regional demand. A simulation of the development without external marketing shows that the internal demand cannot induce a significant increase of the income. BOSERUP (1981) argues that agrarian non-market societies are unwilling to intensify their labour expenditure until population pressure and human survival needs make it imperative. New transport links and the operation of markets bring agricultural innovations to rural populations that may be adopted for other reasons than population pressure. The simulation assumes that transport investments connect the region with the rest of the world and induce a shift towards a market economy, which entails a growth of agricultural production.

(ii) The external demand for agricultural produce is unlimited. Tanzania imports food crops because the internal production cannot satisfy the demand. It is assumed that regional production has no influence on the producer prices (WILSON 1973 p. 208).

(iii) The government conducts an agricultural policy which favours a national food production and secures producer prices, which give sufficient incentives for the farmers. An empirical study in Tanzania 1969-1987 by ERIKSON (1993) shows that peasants respond to price incentives in general[3], but this effect was partly neutralised by the rationing of the consumer goods market. DIERKS (1995 p.46) observed positive price elasticities for various products in Makete between 1987 and 1994 . The improvement of the marketing conditions even caused production increases of other crops, for which the real prices declined slightly.

(iv) A free transport market exists, which allows the free purchase of vehicles and unhindered service an all roads, assuring the evacuation of all crops offered by the farmers.

(v) The sectoral division of labour is not changing significantly during the observed period. This assumption probably does not reflect the real development, because increasing productivity in the agricultural sector would probably entail a growth of other sectors. This assumption was set in order to keep the influences of other factors low.

(vi) The negative experience during the socialist decades leads the farmers to conduct a risk adverse strategy, which primarily secures the family's sub-

[3] Compare KILLICK (1993), pp 203 and 207

sistence by its own production (BRYCESON 1990, p.15). Reactions to market incentives are delayed during the first six years.

(vii) The time saved by transport interventions will be entirely used for direct productive or production related transport activities[4].

[4] Compare however the deliberations in Chapter 2.4.2.

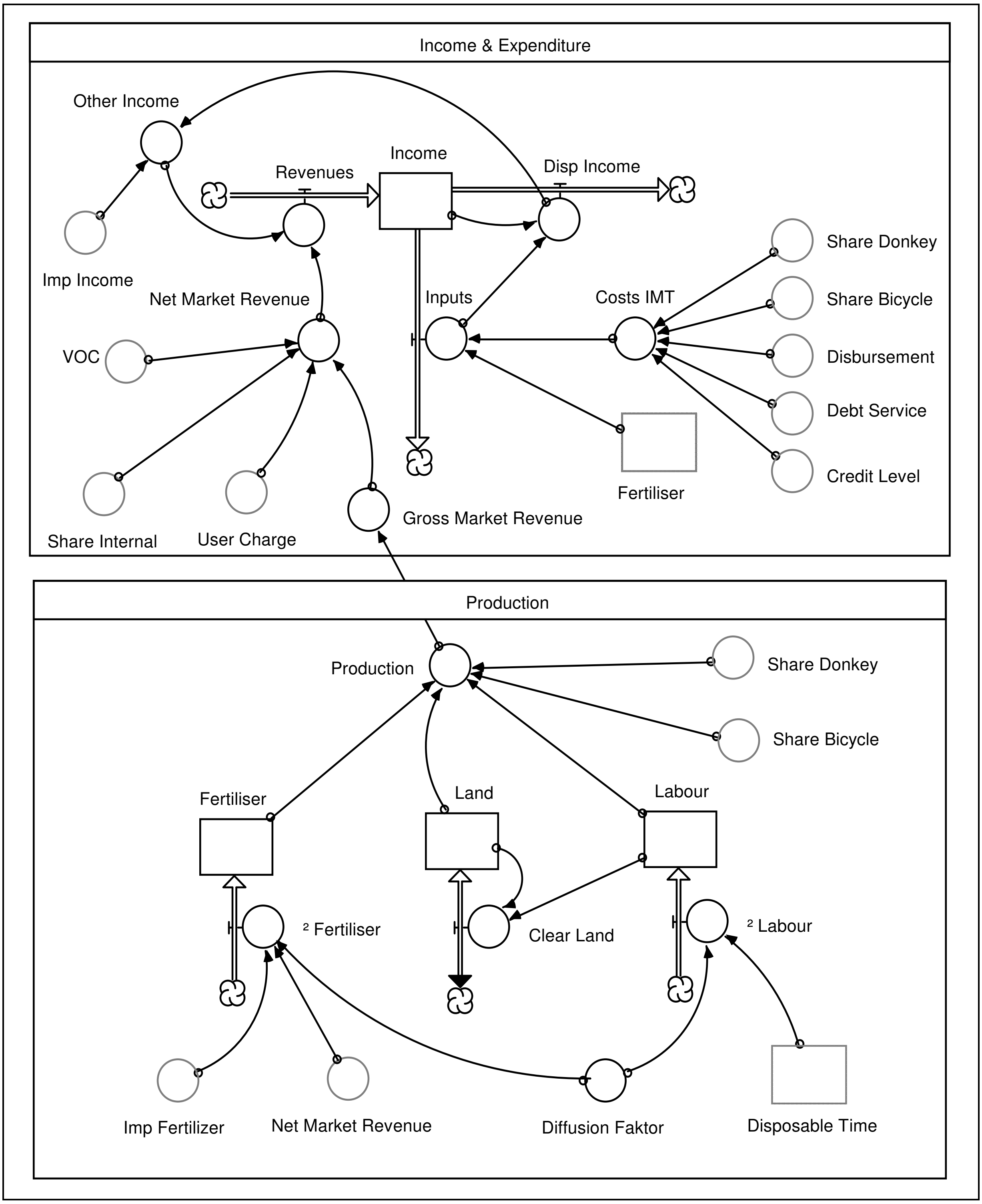

Fig. 5.2-2 The system of income, expenditure and production

5.2.2 *Income and Expenditure*

A visualisation of Income and Expenditure is given in the upper box in Fig. 5.2-2. The "Revenues" of the household consist of the "Net Market Revenue" from agricultural products traded and "Other income" from non-agricultural sources including regular wages, income from artisan work or trading and cash remitted by relatives. The "Net Market Revenues" are dependent on the transport costs of carrying the products to the market. They are obtained by subtracting the transport expenditure (Vehicle Operating Costs "VOC" and "User-Charges"[5]) from the "Gross Market Revenue", which is the result of the production process that will be explained in the next chapter. The addition of "Net Market Revenues" and "Other Income" equals the total "Income" of the household. Before the "Disposable Income" is obtained the costs for the "Inputs" fertiliser and for IMT (Scenario 5 only) have to be subtracted.

The saving rate of a subsistence society is very low[6]. Therefore it is assumed that the households spend all their cash completely until the next harvest. An analysis of the expenditure patterns in Makete showed, that 10 % of the expenditure is spent for regionally produced consumer goods and services[7]. The connector between "Disposable Income" and "Other Income" signifies that an increase of the income results in a growth of "Other Income" in the following year. This small feedback loop causes a slight increase of the total income during the observed period of 20 years. It cannot be the engine for an autonomous regional development process.

5.2.3 *The Production Process*

The production process is visualised in the lower box in Fig. 5.2-2. The households have their main source of cash income from the "Net Market Revenue", which is determined by their agricultural "Production". The amount of harvested products depends on how much input the households use: the farmers have the possibility to change the number of working hours in the fields ("Labour"), the area used for crop cultivation ("Land") and the amount of "Fertiliser" measured in kg. If the total value of the agricultural products is reduced by subsistence consumption, which is assumed to be constant during

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5 "Share Internal" indicates which share of the products is not transported to markets because it is sold within the village (Chapter 5.2.4). The VOC are set at 50 ¢/tkm. The costs include a partly empty return voyage, higher costs for the travel on an earth road, evacuation of the crops with Pick Ups and small trucks and the profit of the vehicle owner. User charges are explained in Chapter 5.4.

6 Anybody who has ever tried to change a bill worth $ 10 knows about the lack of cash in rural areas of Africa.

7 This is made up as follows: 2 % regionally produced consumer goods, 2 % taxes and fees, 4 % social expenditure and 2 % other local expenses.

the simulation period, then the "Gross Market Revenue" mentioned in the previous chapter is obtained. Thus an increase of the inputs will automatically result in a growth of the "Gross Market Revenue" and "Disposable Income".

It is assumed that the households react to the changing marketing conditions by increasing their agricultural production. Because the farmers have practically no assets, they only have the possibility to work longer in their fields. The increase of their labour time is determined by their "Disposable Time"[8] budget for transport and labour purposes, which will be defined in Chapter 5.2.5. It is assumed that every year the household increases the amount of "Labour" used in the fields by $^1/_6$ of their "Disposable Time"[9]:

$$\text{"}\Delta \text{ Labour"} = 1/6 * \text{"Disposable Time"}$$

Fig. 5.2-3 shows that this negative feedback loop causes an asymptotic approximation of the "Labour" curve. The limiting value is determined by the initial "Disposable Time" reduced by the increasing time requirements for transport activities caused by the growing production. This negative feedback loop has a strong influence on the whole model.

The household's "Labour" time in the fields is the main determinant for the growth of the agricultural production. It is assumed, that the agricultural area under cultivation ("Land") is dependent on the "Labour" input; if farmers increase their working time in the fields, the number of acres grows synchronous with the increase of the "Labour" time[10].

The Makete survey demonstrated that an average household spends 10 % of its "Net Market Revenues" on the purchase of fertiliser[11]. Here a positive feedback loop exists: the growing revenues, resulting from the longer working time in the fields, allow higher expenditures for the purchase of fertiliser, which will cause another increase of production.

The Fig. 5.2-3 shows the growth of inputs in Scenario 2, which will be defined later on. All inputs show an asymptotic approximation to a limiting

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8 The "Disposable Time" is set for the initial period. This amount is reduced in every period by the increasing time requirements for trips and for labour on the fields. See also Chapter 5.2.5.

9 The factor 1/6 only determines the speed of the growth process but does not change the results from the scenarios. The factor was set in order to deplete completely the disposable time budget during the modelling period for all scenarios.

10 This is achieved by clearing land if the labour input per acre rises above the Makete average.

11 A linear regression (Multiple R^2= 0.5) shows that the amount of fertiliser grows with the revenues but decreases with the acreage under cultivation. In Bulongwa, where land is available in abundance no fertiliser is used, while in Matamba fertiliser compensates the smaller acreage. In the model it makes no sense to decrease the use of fertiliser with increasing acreage. Therefore the amount of fertiliser will be linked directly to the "Market Revenue" using the mean expenditure for fertiliser observed in Makete.

value, which is mainly determined by the limited time budget. Depleting time reserves will set restrictions on the households to further increase their labour in the fields; the growth process slows down. Restrictions can also be assumed due to the risk averse behaviour of the farmers. After the transport interventions not all farmers take advantage of the new opportunities. During the first third of the modelling period the growth process is slowed down by the variable "Diffusion Factor"[12], which regulates the "Labour" and "Fertiliser" inputs.

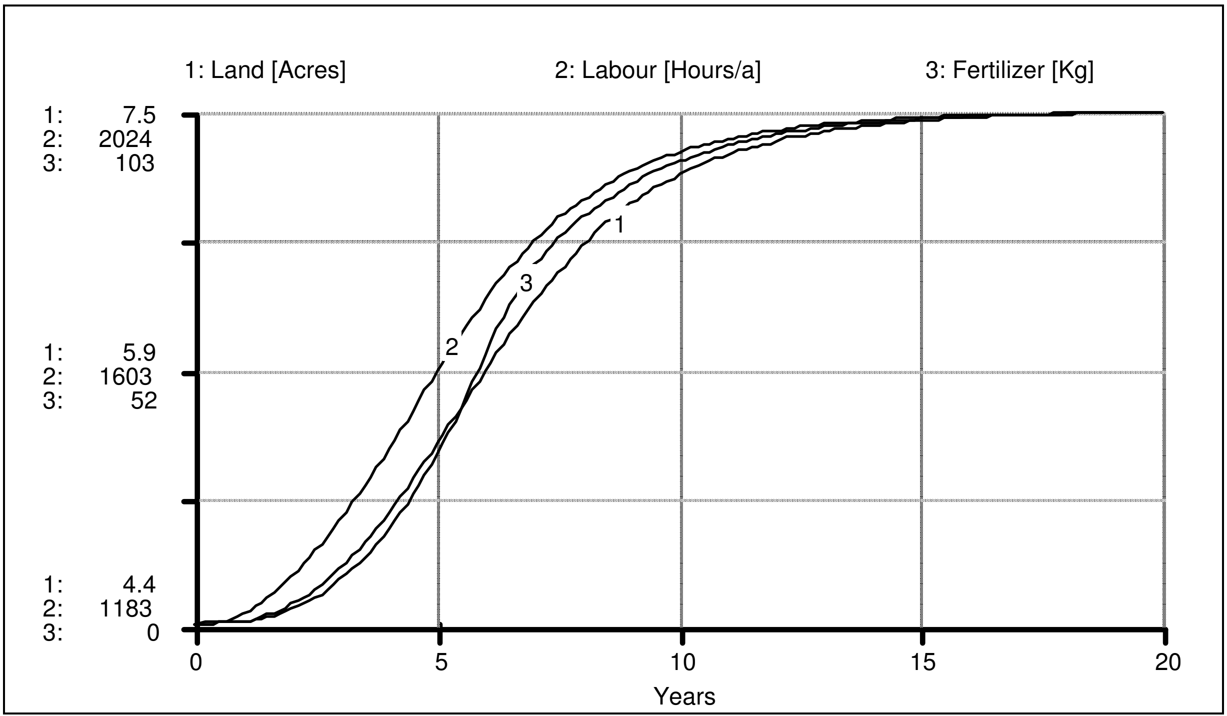

Fig. 5.2-3 Increase of inputs in Scenario 2

Estimation of the Production Function

The Production function describes the nexus between the inputs and the total output of the agricultural production. The input variables "Labour", "Area" and "Fertiliser" were achieved as the results of a multiple regression using the data from the 1994 Makete survey.

A data problem occurred because the measurement of the labour input was subject to uncertainties:

- The number of labour days was assessed by multiplying the working periods with the number of trips. Small misjudgements might lead to big mistakes.
- The duration of the labour days was not measured.

[12] It is assumed that during the first year only 1/6 of the farmers react to the market incentives. This amount increases annually by 1/6 until the sixth year when all farmers react as presumed.

- A few households employ labour in their fields, which was not registered during the survey.
- Some households might be reluctant to give correct data about their production.

In order to eliminate these problems the data set was reduced by the extreme values of the ratio of the crop production per labour day. The frequency histogram given in Fig. 5.2-4 shows that the values above 3.6 $/day can be regarded as extreme values or outliers. The number of extreme values comprises 8 % of the whole sample. Another 8 % of the cases were deleted on the lower end of the frequency distribution. Thus, the number of valid cases is reduced by 16 % to 191.

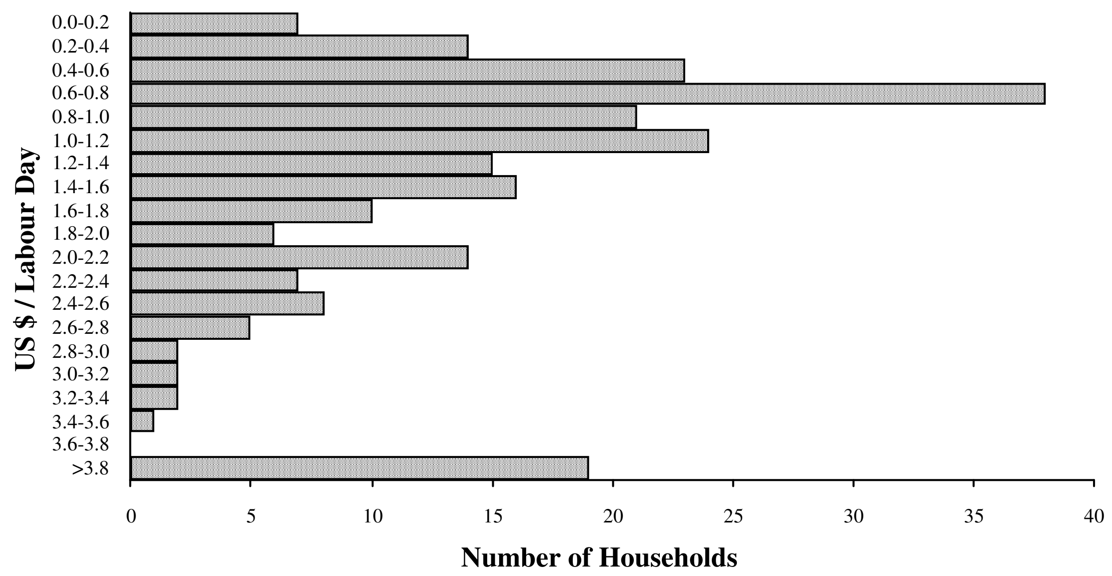

Fig. 5.2-4 Frequency histogram of the ratio crop production per labour day

A non-linear production function of the Cobb-Douglas type was chosen, which has the following general form:

$$Y = k * A^{\alpha} * B^{\beta} * C^{\chi} ...$$

Y	= Agricultural output measured in Dollars
A, B, C, ...	= Independent variables: Area, Labour, Fertiliser, Dummies
α, β, χ, ...	= Coefficients to be estimated in the regression, with $\alpha, \beta, \chi > 0$
k	= Constant to be estimated in the regression

The production function is estimated according to the logarithmic function:

$$\ln Y = \ln k + \alpha * \ln A + \beta * \ln B + \chi * \ln C ...$$

The dependent variable is the agricultural output measured in US$. The relevant independent variables are the following inputs: agricultural area measured in acres, the number of working days on the fields and the amount of fertiliser measured in kg. Dummy variables were created for households possessing bicycles, donkeys or several IMT. The regression was conducted in a stepwise method, which produced significant results. The adjusted R^2 used for multiple regressions amounts to 0.65. If some single villages are regarded the outcome is significantly higher. The F-significance, testing the R^2 against 0 is very satisfying for all of the regressions.

	All Villages	**Bulongwa**	**Matamba**	**Mpangala**	**Utengule**
Adjusted R^2	0.65	0.58	0.70	0.84	0.89
F-Significance	0.0000	0.0000	0.0000	0.0000	0.0000
Number of Cases	191	77	108	40	11

Tab. 5.2-1 Results from log-linear regressions

Variables	Coefficient α, β, χ	Standard Regression Coefficient	T-Significance	Tolerance
Labour [days]	0.440365	0.455838	0.0000	0.563966
Land [acres]	0.372422	0.324492	0.0000	0.591773
Fertiliser [kg]	0.049917	0.169441	0.0003	0.863331
Dummy Donkey	0.448120	0.183601	0.0001	0.865809
Dummy Bicycle	0.289104	0.160612	0.0005	0.881359
Dummy IMT	0.726777	0.145727	0.0008	0.974751
Constant k	9.294093		0.0000	

Tab. 5.2-2 Coefficients and statistical tests for the regression

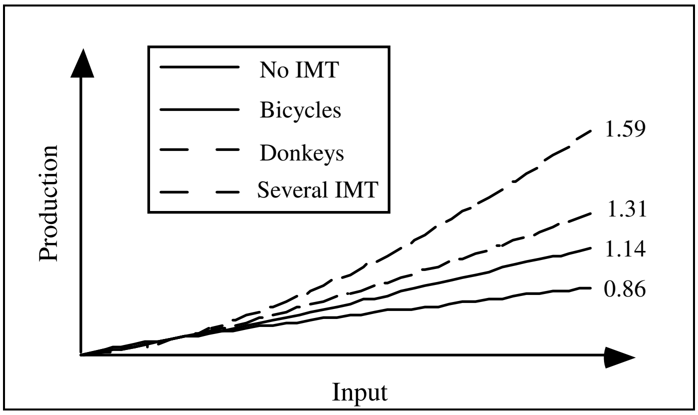

Fig. 5.2-6 Production function for different households in Makete

The coefficients and the constant show a very high T-significance and the relatively high tolerance values seem to exclude the possibility of a collinearity of the variables. The Durbin Watson-Coefficient which is an indicator for the autocorellation, is located in the acceptable interval[13] between 1.5 and 2.5. In Fig. 5.2-5 the cumulated frequency of the residuals are compared with the expected normal distribution, which is represented by the diagonal on the graphs. The graph visualises, that the residuals of the estimated Cobb-Douglas function are almost normal distributed.The Production function plotted in Fig. 5.2-6 describes the growth of the production of different household types according to the results from the regression. If households which do not possess an IMT increase their inputs by the factor λ, their production will grow by $\lambda^{0.9}$. Households owning a bicycle will increase their production by $\lambda^{1.1}$, households with donkeys by $\lambda^{1.3}$ and with several IMT even by $\lambda^{1.6}$. This means that **the possession of donkeys or bicycles will enable the household to change its productivity from decreasing to increasing returns to scale.**

The question arises, if the growth in productivity stems only from the possession of the IMT or whether only active households which already have high productivity are able to purchase these means of transport. On the other hand it can be argued that the IMT

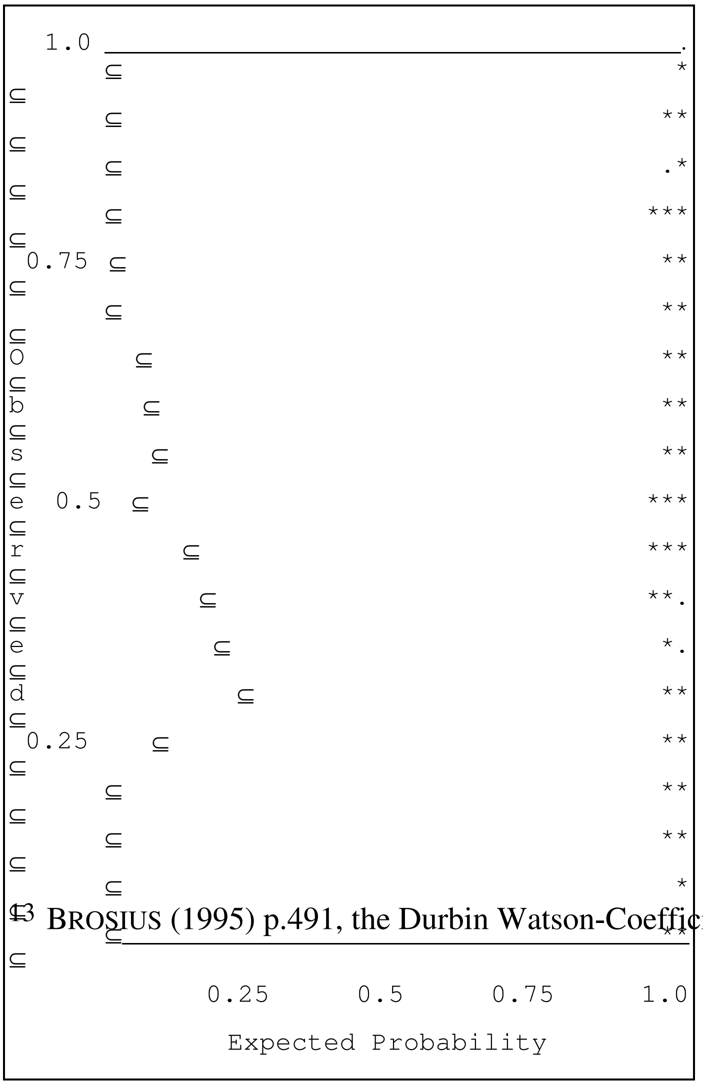

Fig. 5.2-5 Normal probability plot of observed and expected residuals

13 BROSIUS (1995) p.491, the Durbin Watson-Coefficient was calculated at 1.85.

enable the farmers to produce more efficiently:[14]

- Reduced effort and drudgery of human porterage might increase the labour productivity.
- Pest damage and spoilage due to transport at crop harvest time is reduced.
- It is possible to cultivate further distant plots, where fertility might be higher.
- Distant markets where producer prices are higher are more easily accessible.

Because the sample of households with several IMT is fairly small (10 cases) only the production functions of bicycle and donkey posessing households will be used henceforth.

5.2.4 The Transport Sector

The transport sector, given in Fig. 5.2-7, was calibrated by the data collected in Makete. The most important variable is "Trans Time", which represents the total time used for the household's transport activities. It is the sum of the time used for market trips ("Time Market"), the time for the trips to the fields ("Time Fields") and the other transport ("Other Time"), which consists mainly of transport for subsistence tasks like water and firewood collection.

The trips to the fields are determined by the number of working days ("Labour") and the distance from the homestead to the fields ("Dist Field"); the latter grows with the enlarging cultivated area ("Land")[15]. The transport to the markets is more difficult to assess: the Makete survey showed that a part of the

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14 Compare AIREY (1992)

15 Result of linear regression of acreage and distance to the fields:
Distance Fields = 2.89 + 0.14 * Acres

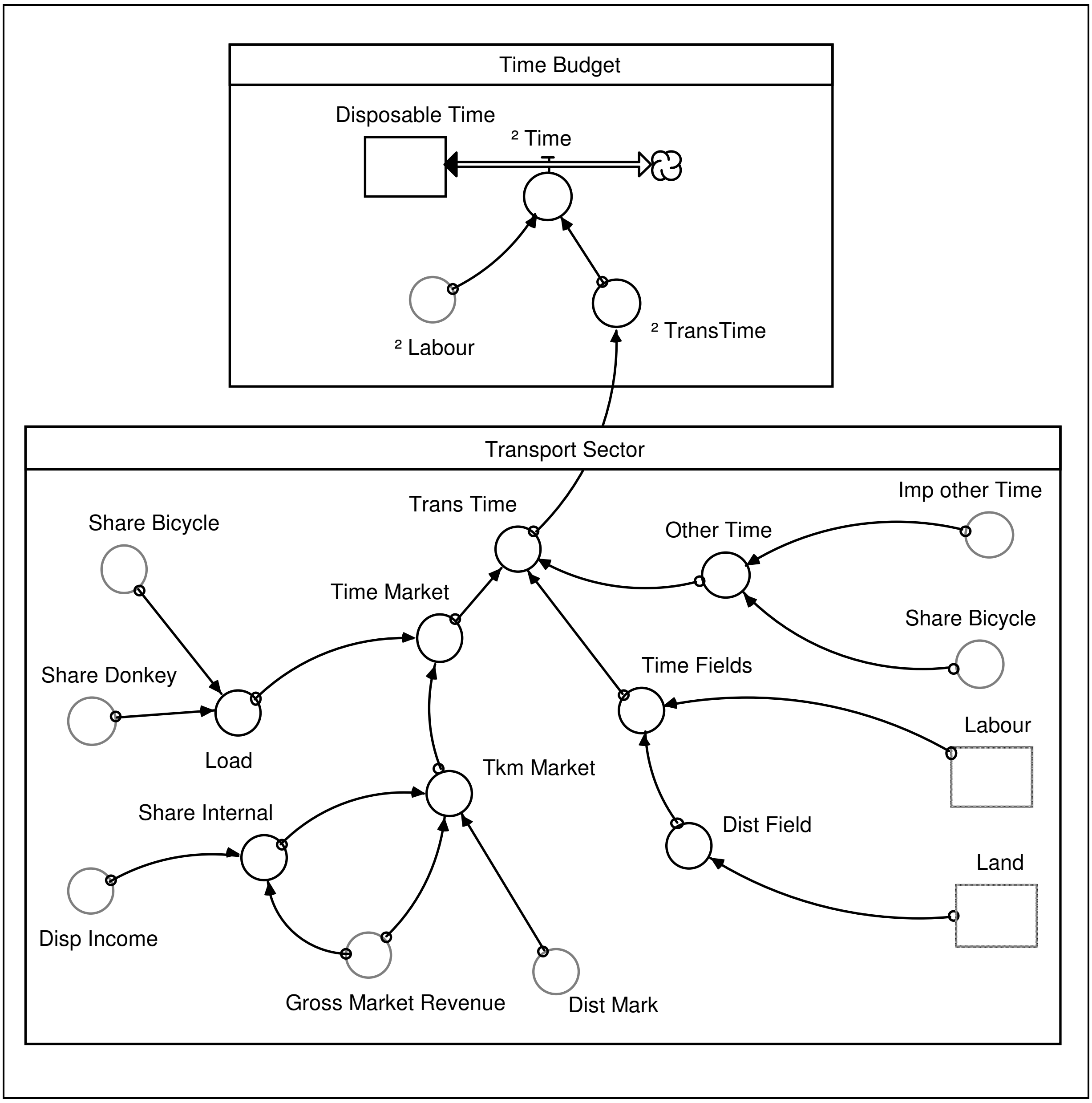


Fig. 5.2-7 The transport sector and the time budget

"Disposable Income"[16] is spent in the village to purchase food crops from other farmers. Therefore households market a share of their agricultural products internally ("Share Internal") and transport the remaining amount to external markets. The tkm for market transport ("Tkm Market") can be achieved by multiplying the weight of products marketed ("Gross Market Revenue") with the distance to the markets. It is assumed that the internal marketing distance is the average distance to the village centre. The distance to the external market or to the collection point ("Dist Mark") varies with the scenarios. The "Tkm Market" is the basis to estimate the time for marketing trips ("Time Market") by using

[16] It was estimated that in Makete 12 % of the expenditure was spent for locally produced food crops.

the "Load" factors for different transport modes. In the Scenarios 1-4 all products are transported by headload with an average "Load" of 20 kg per trip. In Scenario 5 donkeys or bicycles are used for many transport purposes and the average load can be increased to 40 kg per bicycle and 60 kg per donkey. It has to be assumed that not all the crops are transported with the IMT: only 40 % of the products are carried by the households possessing a bike, but 80 % by households owning a donkey. The variables "Share Donkey" and "Share Bicycle" indicate which percentage of the households possess an IMT. The time which households use for subsistence transports ("Other Time") can be influenced by the possession of bicycles and transport avoiding measures ("Imp Other Time"). The use of donkeys for subsistence transport is plausible, but was not observed in Makete.

The households in the model region increase their marketing of agricultural products during the observed period. This expansion entails growing transport needs for production and marketing related transports. Fig. 5.2-8 shows the change of the total transport time ("Trans Time") in Scenario 2. The time used for subsistence trips ("Other time") which dominates total transport time remains constant, while the time for market trips and trips to the fields increases and entails a growth of the total time devoted for transport ("Trans Time").

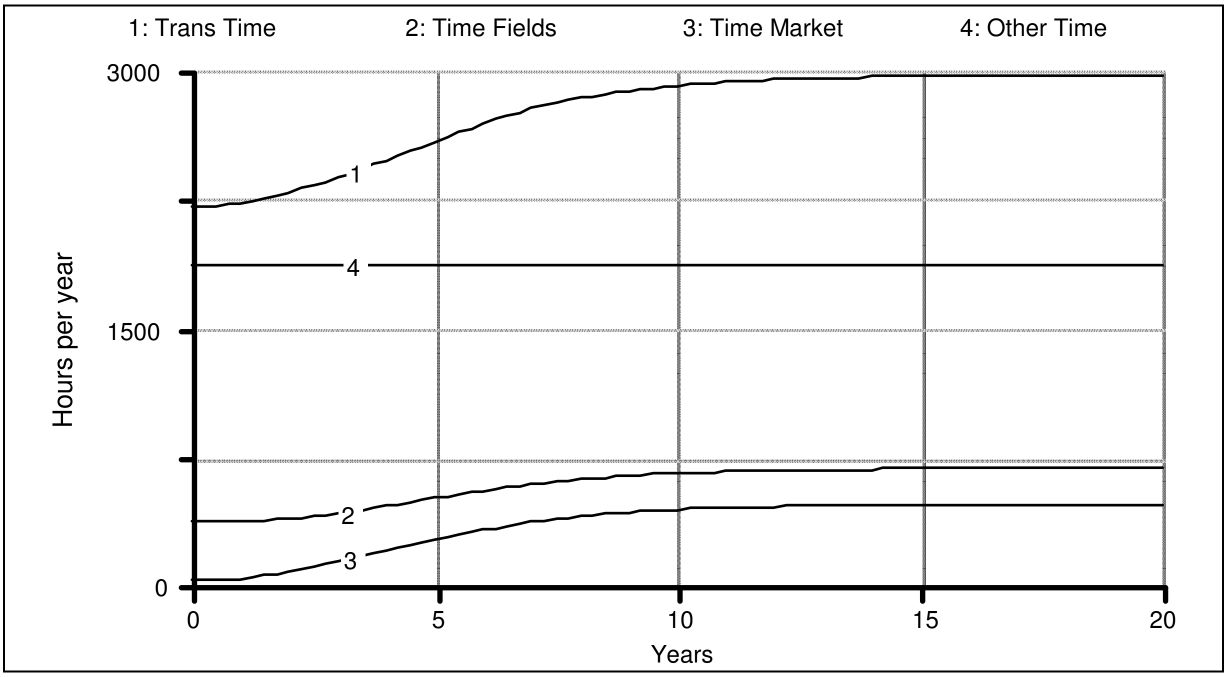


Fig. 5.2-8 Transport time in Scenario 2

The different transport interventions in the various scenarios discussed later on have direct impacts on the following variables:

- "Dist Mark": the distance to the markets and collection points are changed by the construction of roads.
- "Imp other time": subsistence transports are reduced by transport avoiding measures.
- "Share Bicycles", "Share Donkeys": the purchase of IMT is promoted.

A change of the variables has an impact on the total time used for transport purposes ("Trans Time") which entails a change of the "Disposable Time" budget. With the help of these changes the whole production system is influenced.

5.2.5 The Time Budget

The "Disposable Time" budget plotted in Fig. 5.2-7 is the steering element in the whole model. It is assumed that every household has a constant time budget which is **exclusively used for the labour in the fields and for transport purposes**. The time for the household's non-transport-tasks and for leisure time is excluded from the "Disposable Time" budget. The time budget is set at 5,000 hours per year. A detailed discussion of the assumptions including sensitivity tests is given in Chapter 5.4. This budget is reduced by the time requirements for transport and labour in the fields. In the first year before the transport interventions are undertaken a household uses 3,400 hours for labour and transport in order to cover its subsistence needs. This implies that 1,600 hours are still disposable. The increasing production in the following years entails a growth of the transport and labour time: every year of the simulation period the increased time requirements for labour ("Δ Labour") and transport (Δ Trans Time) are subtracted from the "Disposable Time" budget. Fig. 5.2-9 shows the depletion of the "Disposable Time" budget, while the amount of time used for labour and transport increases during the development process[17]. The effects of the different scenarios are achieved by distributing the disposable time between labour and transport. It can be stated that in none of the scenarios does the labour time exceed the household's time for transport activities!

The depletion of the time budget is the reason for the reduced growth of labour and transport time. Fig. 5.2-3 shows that the "Disposable Time" determines the growth of "Labour" in the fields. This is the most important feedback loop in the system, which regulates the production system. A change in the transport system reduces the time requirements for transport and leaves more time for directly productive labour. The model shows, that different

[17] It should be mentioned that the sum of "Disposable Time", "Trans Time" and "Labour" remains constant at 5,000 hours. The growth of "Δ Labour" was regulated in a way, such that for all scenarios the disposable time budget is completely depleted after 20 years.

transport interventions have different impacts on the time budget and thus on production and income.

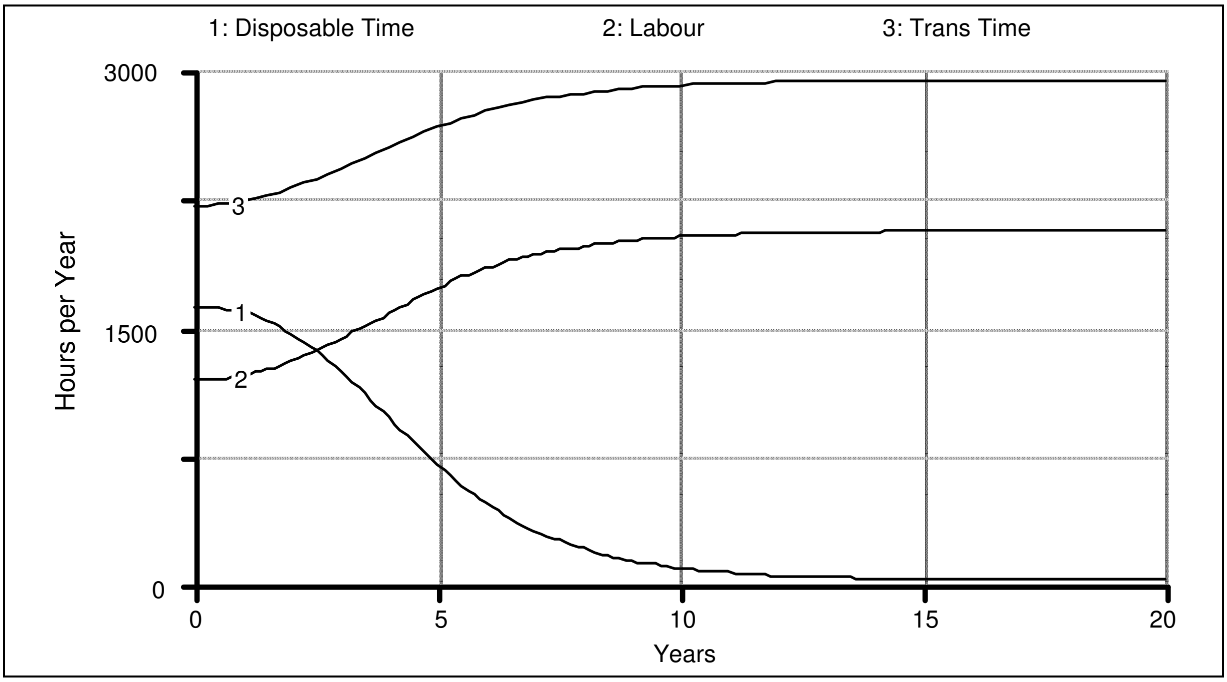
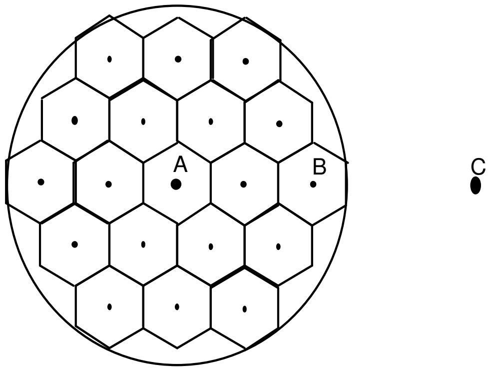


Fig. 5.2-9 Time budget in Scenario 2

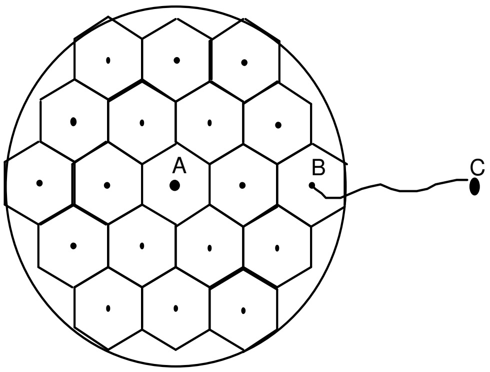
5.3 Impacts of Transport Interventions

Five scenarios were developed to assess the impacts of different transport interventions in a region which is initially completely isolated and primarily subsistence oriented. Only a small share of agricultural production is traded on the village markets to satisfy local demand which is caused by the non-agricultural income. Without any modification of the transport system no change of the production and marketing patterns would occur and the economy would only increase with the growing population. The model region was designed with an idealised spatial structure based on the data from the Makete district. A sketch of the region and the main features of the scenarios are listed in Fig. 5.3-1. The region is made up of 19 villages of the same size which are equally distributed over the area and where 20,500 persons live in 4,180 households.The effects of the scenarios are presented for an average household in the region.



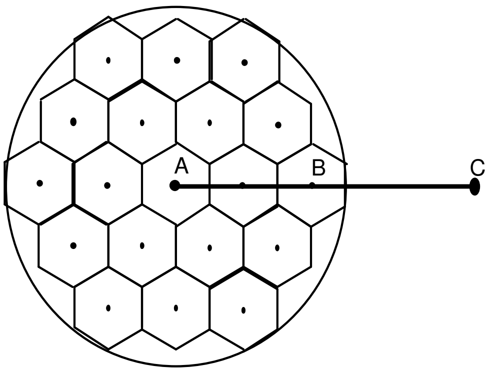
Base Conditions

Inhabitants:	20,500
Density:	18 Inh/sqkm
Households:	4,180
Distance Market C:	No Connection
Distance Village Market:	1.6 km



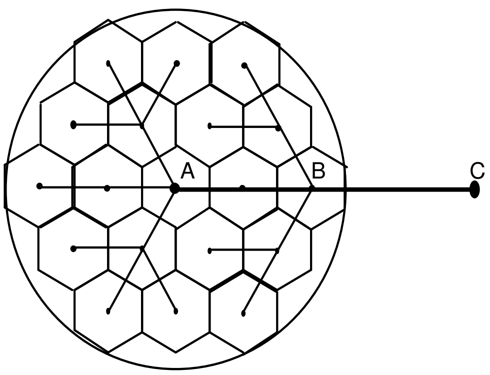
Scenario 1:
Regional Footpath

Length: Footpath:	15 km
Distance Market C:	33 km
Investment Costs:	9,300 $
Maintenance Costs:	560 $/a
Wages (Investment):	1.00 $/HH
Wages (Maintenance):	0.10 $/HH



Scenario 2:
Feeder Road

All Weather Road:	30 km
Distance Collection Points	9.5 km
Investment Costs:	123,000 $
Maintenance Costs:	7,000 $/a
Wages (Investment):	17.40 $/HH
Wages (Maintenance):	1.00 $/HH



Scenario 3:
Feeder Road + Local Tracks

All Weather Road:	30 km
Dry Weather Track:	138 km
Distance Collection Points:	1.6 km
Investment Costs:	318,000 $
Maintenance Costs:	18,000 $/a
Wages (Investment):	36.50 $/HH
Wages (Maintenance):	2.50 $/HH

Fig. 5.3-1 Main features of the scenarios

Scenario 1: Footpath Construction

Initially no transport link between the region and the external market C exists. It is assumed that a natural barrier like a river or a steep escarpment, as in the case of Utengule, obstructs any trade between the region and the market C. The distance between village B and the market C comprises 15 km; the same length as the distance between Utengule and Ng'yekye. The construction of a footpath simulated in Scenario 1 causes an increase in the transport to the market place. The scenario calculates the behaviour of an average household in the region: the average distance to the market is 33 km, which is exclusively covered by walking. The participation of the villages will probably decrease with increasing distance to the market. The construction costs at $ 9,300 are relatively low as well as the wages earned by inhabitants of the region. Because there is no road access into the region, fertiliser cannot be purchased and thus will not be used as an agricultural input.

Curve 1 in Fig. 5.3-2 shows that the labour input after a time of adaptation will increase exponentially. But the restrictions in the time budget limit the labour input to less than 1,900 working hours per year. The main reason are the growing transport needs especially for trips to the markets, which occupy nearly 700 hours per year (Fig. 5.3-3 curve 1). Fig. 5.3-4 shows that the construction of a footpath induces a growth of the total production of $ 70. The disposable income plotted in Fig. 5.3-5 could even increase slightly more due to the employment revenues during the construction phases and the regional income feedbacks.

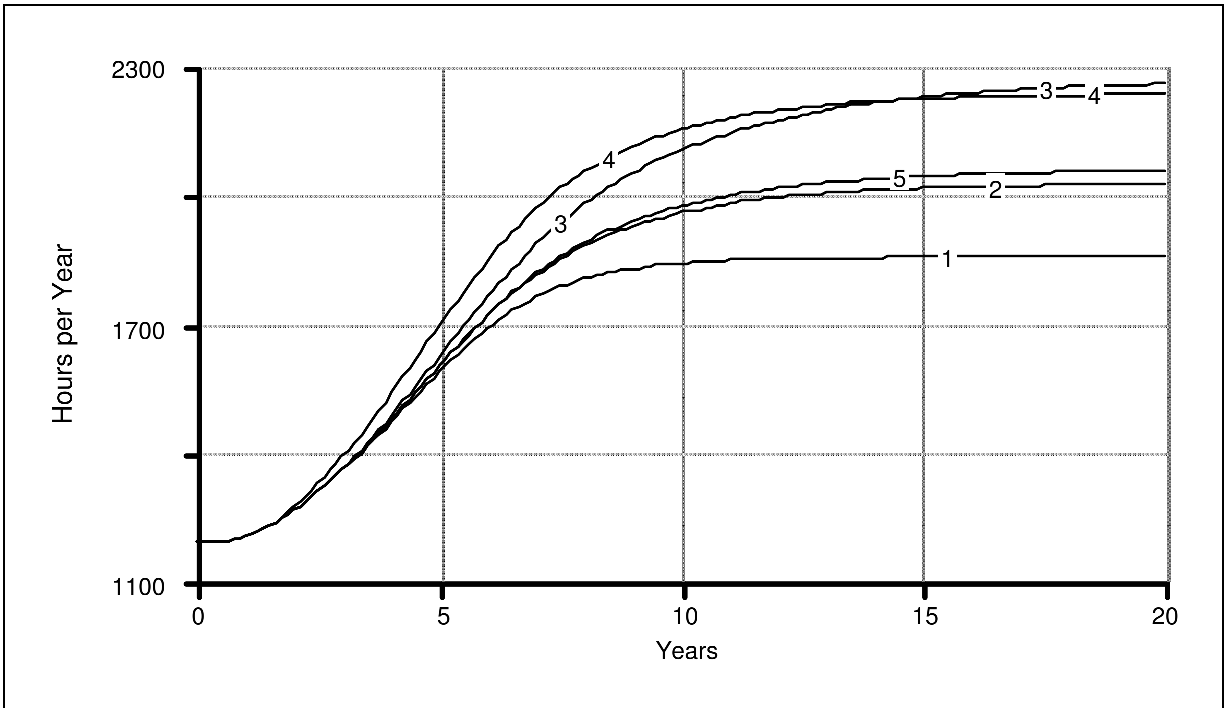


Fig. 5.3-2 Labour input in all scenarios

The Scenario 1 reflects the situation of the Bulongwa Region in 1994: the road access is very bad and a big share of the products are transported by headload over long distances to the external markets. The survey observed marketing revenues in Bulongwa of $ 48 which the model simulates after a period of four years after the footpath construction. After 10 years of simulation the revenue stagnates at $ 80 per household. The transport conditions and the limited time budget do not allow a further increase of the market production. New transport interventions are necessary to make another increase of the market production possible.

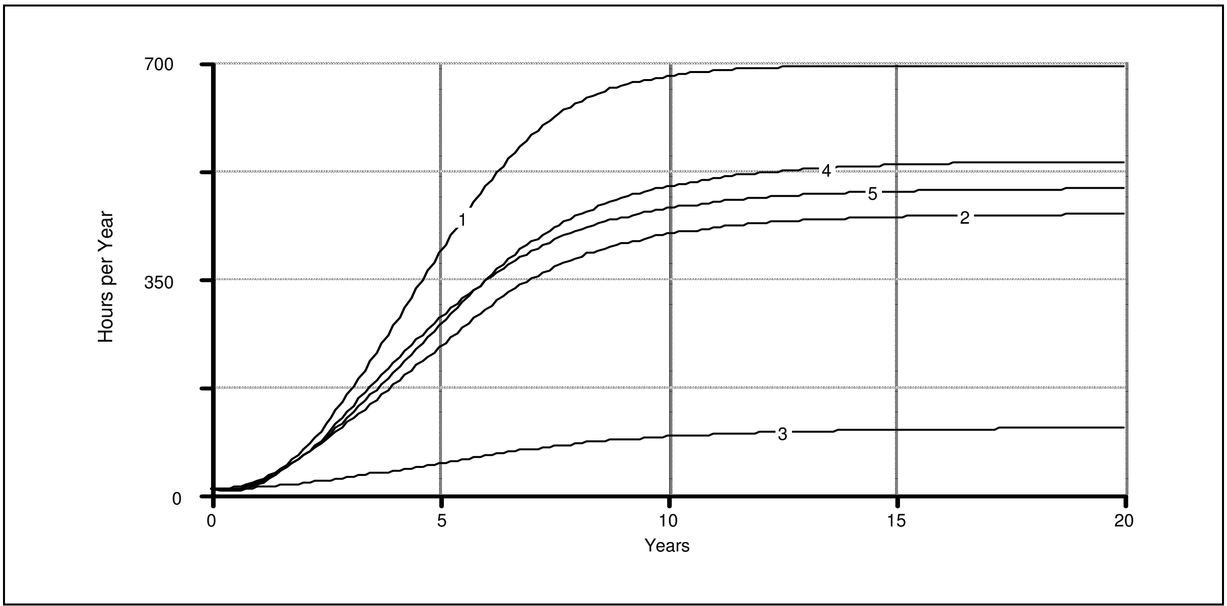


Fig. 5.3-3 Transport time for marketing trips in all scenarios

Scenario 2: Construction of a Feeder Road

This scenario simulates the construction of an all weather road, which leads from external market C to regional centre A (see Fig. 5.3-1). 30 km are constructed with labour based technologies and low cost standard. The investments amount to $ 123,000 and the annual maintenance to $ 7,000. Three points are installed on this road, where agricultural produce are collected and inputs delivered. The farmers still have to transport their products over an average distance of 9.5 km. Curve 2 in Fig. 5.3-2 shows that the labour input could be increased significantly compared to Scenario 1, which is mainly due to reduced transport time for marketing trips (Fig. 5.3-3). The growth of the inputs made it possible to increase agricultural production by $ 160, which is much stronger than the growth in the previous scenario. The disposable income[18] (Fig. 5.3-5) did not

[18] The income curves for the scenarios 2 to 5 show a decline after the first year, which is due to declining employment after the termination of the construction phases.

grow as fast as the production, because the transport costs reduce the marketing revenues. It can be stated that the economy is stagnating after a rapid growth of the production of up to 10 % per annum during the first half of the simulation period. Time restrictions are the main reason for the declining inputs.

Scenario 2 can be compared with the situation in Matamba Region in 1994 where an all weather road gives access for motorised vehicles and allows the evacuation of agricultural produce. The average marketing revenues in Matamba amount to $ 122, which the model simulates 8 years after the road construction. After 15 years of simulation the revenues stagnate at $ 137. This signifies, that without further technological changes the regional development will be hampered in the near future.

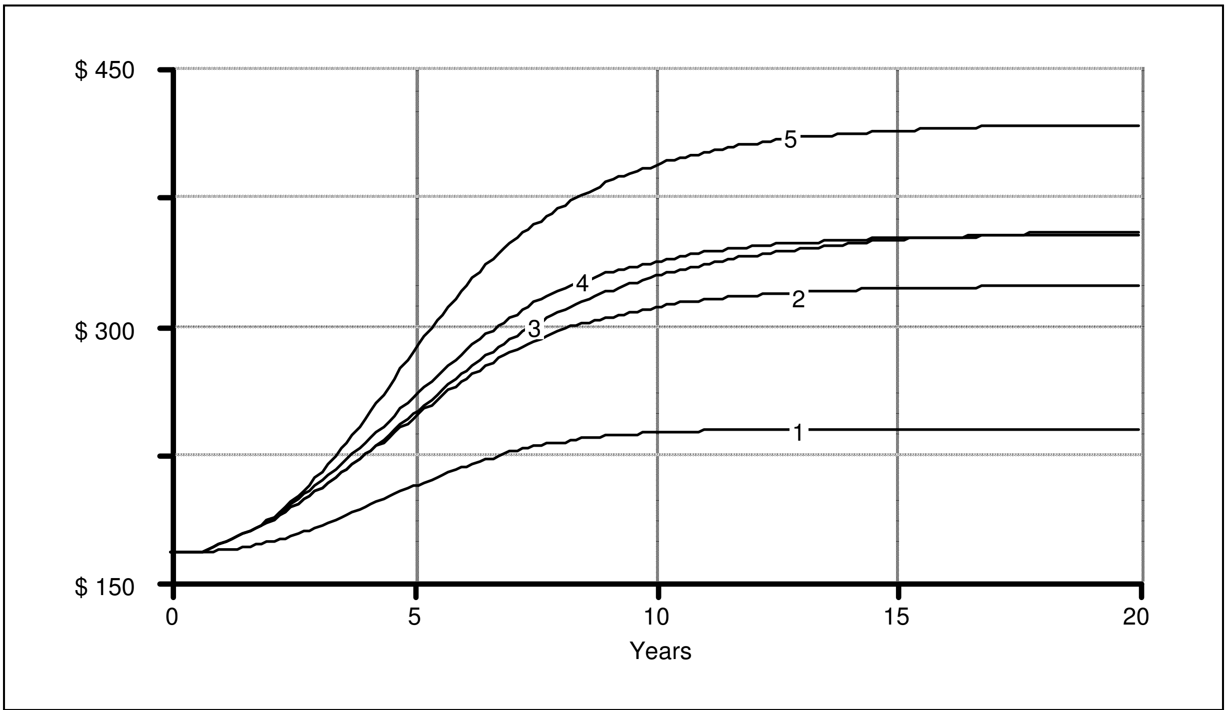


Fig. 5.3-4 Agricultural production in all scenarios

Scenario 3: Motorised Access to all Villages

The third scenario assumes that every village receives access to a dry-weather track, while the regional centre is accessible by an all-weather-road as assumed in Scenario 2. The low-cost-construction of 138 km of local tracks and 30 km of the feeder road costs $ 318,000 and annual maintenance amounts to $ 18,000. The farmers can market all their products in the village centre, which is on average 1.6 km away from their homestead. This scenario computes the least time requirements for marketing trips (Fig. 5.3-3) and allows an increase in labour time in the fields (Fig. 5.3-2). After 20 years, production increased by $ 189 and disposable income grew by $ 146. The higher transport costs reduce the net benefits of the Scenario 3: compared to Scenario 2 the disposable income increases by only $ 18 per household. The question arises as to whether the higher investment and maintenance costs for the local tracks can be warranted or whether other investment opportunities with higher rates of return exist. The following two scenarios will try to answer this question.

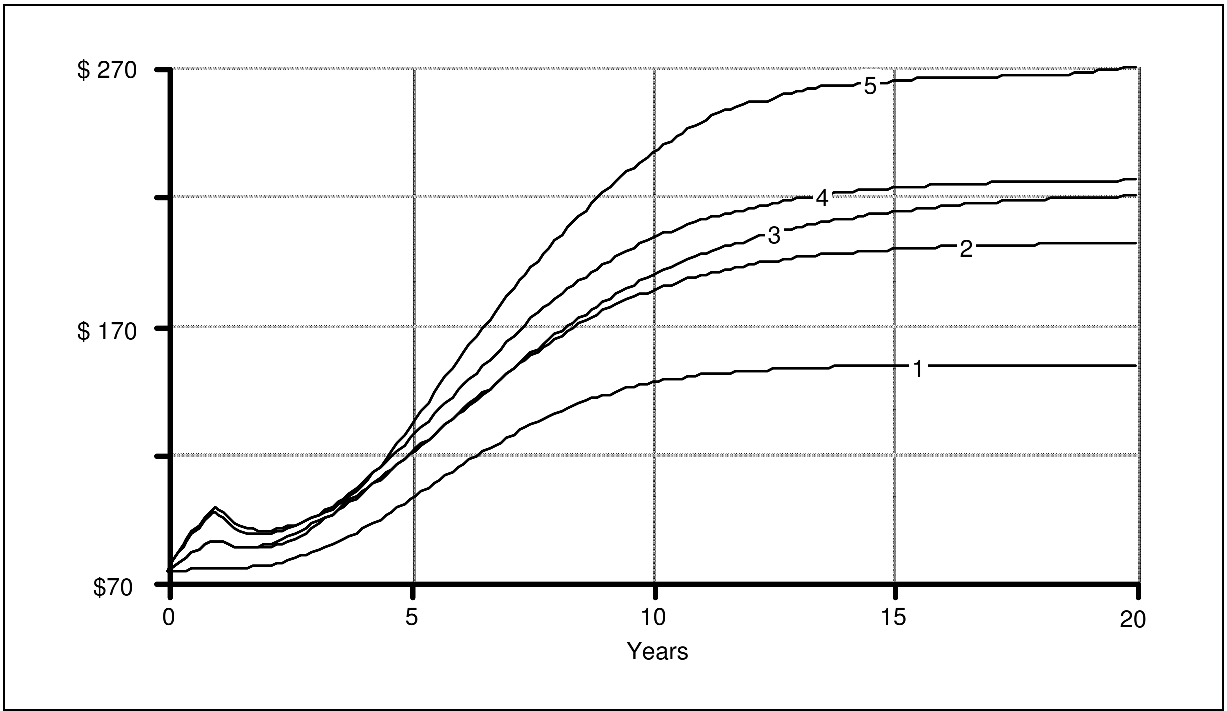


Fig. 5.3-5 Disposable income in all scenarios

Scenario 4: Transport Avoiding Measures

Scenario 4 tries to relieve the household's time budget by reducing the household's transport for subsistence tasks. Every village receives low cost wells, which reduce the average walking distance to the water source as observed in Makete. The number of trips for firewood collection are reduced by 40 % if low consumption stoves are introduced. Both measures cause a reduction in the subsistence transport time ("Other Time") of 388 hours per year. On top of that the feeder road constructed in Scenario 2 will be built as well. The total investment costs amount to $ 473,000 and annual maintenance comprises $ 10,000. If the costs are added over the whole simulation period (without discounting) then the total amount is comparable with the cumulated costs of Scenario 3.

The time savings by the reduction of subsistence transport are to 55 % used to increase the labour time, which gives rise to production growth and entails an increase of production related transport activities. The total production grows by $ 186, which is slightly lower than the increase induced in Scenario 3 but well above the increase in Scenario 2 (Fig. 5.3-4). The model shows that transport avoiding measures can have the same impacts on production as the construction of local roads. If the disposable income is regarded, the transport avoiding measures have a slightly stronger impact than the track construction due to lower transport costs. The impacts on the health- and environmental situation cannot be assessed in monetary terms.

Scenario 5: Promotion of Intermediate Means of Transport

In Scenario 5 the effects of the promotion of IMT are assessed. The precondition is the construction of a feeder road, as simulated in Scenario 2. In addition, donkeys and bicycles are promoted by the provision of credit. A revolving credit fund is installed, which provides credit for the farmers, who want to purchase a donkey or a bicycle.The field study shows that 30 % of the households want to purchase a donkey and 60 % a bicycle. The main restriction seems to be lack of funds. 82 % of the households that prefer a donkey and 92 % of the households wishing to purchase a bicycle state that the IMT are too expensive for their small budgets. While the price for a donkey is estimated at \$ 88 the willingness to pay (WTP) comprises only \$ 20. Bicycles cost \$ 74 and the WTP is estimated at \$ 15. Scenario 5 assumes that the IMT will be credited at 75 %. The purchase of IMT in the model is related to the development of the "Marketing Revenues". The willingness to pay observations already mentioned in the Chapters 4.4.1 and 4.4.2 were set in relation to the marketing revenues and a demand curve was derived for the donkeys and bicycles. It is assumed that the IMT can be used for ten years until they break down or die. In this case another IMT will be purchased using the credit system again.

Credit Level	Share Bicycle	Share Donkey	Increase of Disposable Income	Annuities Donkey Households	Annuities Bicycle Households	Credit Fund
0 %	13 %	2 %	\$ 143	0	0	0
50 %	29 %	11 %	\$ 172	\$ 12	\$ 10	\$ 34,000
60 %	34 %	13 %	\$ 179	\$ 15	\$ 12	\$ 53,000
70 %	41 %	15 %	\$ 189	\$ 17	\$ 14	\$ 73,000
80 %	46 %	21 %	\$ 204	\$ 18	\$ 15	\$ 98,000
90 %	50 %	27 %	\$ 219	\$ 22	\$ 18	\$ 133,000

Tab. 5.3-1 Effects of different credit levels at the end of the simulation period

The growing revenues during the development process will enable an increasing number of the households to purchase an IMT. In Scenario 5 the share of donkey possessing households increases from 0 % to 18 % while the share of bicycle owning households reaches 44 % at the end of the simulation period. The possession of IMT causes a shift of the production function from decreasing to increasing returns to scale, which gives rise to a rapid growth of the agricultural production. At the end of the simulation period the production per household increased by \$ 250 (Fig. 5.3-4), which is \$ 60 more than in the best road scenario (Scenario 3). The disposable income increased by nearly \$ 200 (Fig.5.3-

5), which is $ 44 more than in Scenario 4. The strong impacts from the IMT stem partly from reduced time requirements for production and marketing related transport, while a considerable share is caused by the change in the production function.
Scenario 5 assumes a credit level of 75 %. The variation of this level can influence the results significantly. Table. 5.3-1 shows the effects of different credit levels. If the IMT are simply promoted but no credit system is installed, than after 20 years 13 % of the households would be able to purchase a bicycle and only 2 % a donkey. The disposable income would grow by $ 143, which is $ 15 more than the increase in Scenario 2. Stronger effects can be achieved if the credit level is increased. If 90 % of the price could be covered by credits then 50 % of the households would own a bicycle and 27 % a donkey. This would increase the disposable income by $ 219, which is $ 90 more than in Scenario 2 or $ 72 more than Scenario 3. Fig. 5.3-6 plots the effects of different credit levels on the disposable income at the end of the simulation period.

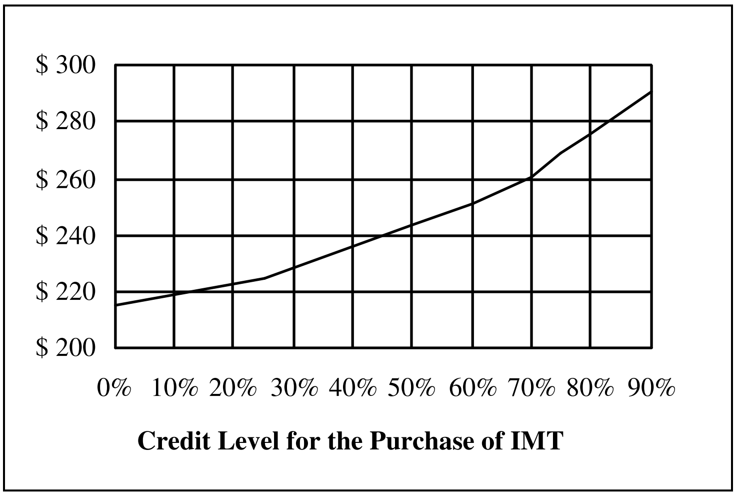


Fig. 5.3-6 Impacts of the credit level on disposable income after 20 years

One of the main problems connected with small scale credits are the high overhead costs. Therefore a real interest rate of 12 % was assumed[19]. Another problem is the low repayment quota. Therefore it is assumed in the model that only 80 % of the credits are paid back. The Grameen Bank in Bangladesh seems to be a good example how these high costs can be externalised[20]. The responsibility for the credit distribution and the debt service payments lies within a group of creditors. Group pressure and social responsibility towards the other members seems to be the main reason for the high repayment quota of over 98 % in Bangladesh.

[19] The real interest rates of small scale credit schemes for IMT range between 3.5 % in Burkina Faso and 11 % in Sri Lanka and Bangladesh (International Forum for Rural Transport and Development, Forum News, Vol. 2, June 1994).

[20] See Neue Züricher Zeitung 24.6.1995 "Auch arme Menschen sind kreditwürdig".

The West African 'Tontine', a traditional female saving club[21], could be an appropriate form of organising the credit system in Africa. Credit distribution to women could solve many of the problems concerning IMT:

- Nowadays in 63 % of the households men have the control over the resources (JENNINGS 1992, p 27). Jennings quotes a Makete women: "Why would men buy a donkey when they can buy another wife to do the work".
- The IMT are possessed by men and mainly used for the purpose of cash crop transport, but only in a few cases to reduce the transport burden of the female tasks (see Chapter 4.4). During non-harvest periods the donkeys were left in the mountains. Ladies' bicycles could not be found in Makete.
- The experience with saving groups shows that the reliability of women in money matters seems to be much higher than for men.

The simulation assumes a period of repayment of 5 years after the purchase of the IMT, which results in the annuities given in Tab. 5.3-1. The annuities are deducted from the income as described in Chapter 5.2.2. The debt service seems to be low in absolute terms, but it is quite high if it is compared with the low cash income. But the high production increase after the purchase of the IMT makes the debt service possible. It has to be recalled that households possessing donkeys in Makete had roughly twice the income of comparable non-donkey-households (Chapter 4.4.1).

The debt service is paid into a revolving fund, which is used to give new credits to other non-IMT-households. Assuming a credit level of 75 %, the maximum cash need of $ 84,000 would be reached after six years. If no credits are distributed to replace old IMT[22], the fund would reach positive values after 12 years and at the end of the modelling period a surplus of more than $ 16,000 can be accumulated. Tab. 5.3-1 shows that increasing credit levels entail a growing need of start capital for the credit fund. A credit level of 90 % necessitates $ 133,000, which is still much lower than the investments for local tracks (Scenario 3) or for transport avoiding measures (Scenario 4).

5.4 Sensitivity Testing of the Time Budget

Time restrictions are the most important constraint for the simulated development process. The Makete survey shows that annually 1,420 hours can be regarded as labour time, while 2,439 hours were used for transport activities. The total "Disposable Time" budget sums up to 3,900 hours per year. A com-

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[21] The 'Tontine' is a traditional female saving group in West Africa, which provides credits for commercial or social purposes to its members. The money stems from individual contribution of the participants. The repayment of the debt is enforced by the group pressure.

[22] In the model it is assumed that an IMT can be used for 10 years and the replacement is financed with a new credit. In this case the credit fund will not reach positive values during the simulation period.

parison with other African studies (Tab. 5.4-1 and Tab. 2.3-1) shows that the labour time in Makete ranges at the end of the scale. The market production in Makete is still very low and an increasing market integration would imply a growth of the labour time in the fields. If it is assumed that the daily budget for transport and labour per able-bodied person comprises 7 hours during 310 days of the year, **then the disposable time per household can be set at 5,000 hours/year**[23]. An increase of more than 1,000 hours per household seems to be quite strong, but it has to be mentioned that already one quarter of the households in Makete are using more than 5,000 hours for transport and labour.

Hours/Year	Labour Time for Crop Cultivation			Transport time			Total	Study
	Male	Female	House-hold	Male	Female	House-hold		
Makete 1994			1420	503	1562	2439	3859	Makete Survey
Makete 1986/87				531	1648	2475		Barwell/Malmberg
Tanga						2083		Dawson et al 1993
Cameroon 1962-64	1077	1355	2432*	1300	1542	2842*	5274*	Tissandier 1970
18 Field Studies	825	1100	1925*					Boserup 1989
Togo 1981			1233					Midhoe 1982
Gambia	740*	920*	1660					Cleave 1974
Uganda 1963/65			2200					Cleave 1974
Malawi 1972	665*	1715*	2380					Dasgupta 1977
Kenya 1956/57			1911					Clayton 1960
Ghana 1970	992*	833*	1825*					Wagenbuur 1972
* Estimate								
Sources: BARTH/HEIDEMANN 1987, BARWELL/ MALMBERG 1989, LEVI 1982, DAWSON BARWELL 1993, Boserup 1989, Makete Survey 1994								

Tab. 5.4-1 Time budget for labour on the fields and transport

The annual time used in Makete for transport and labour amounts to 3, 900 hours, while in the model the budget was set at 5,000 hours by using crude assumptions. The sensitivity analysis in Fig. 5.4-1 plots the change of the disposable income during the simulation period under different time restrictions in all scenarios. The graph shows that the setting of the time budget has impacts on the level of production and therefore on the disposable income. The main purpose of the model is not to estimate exactly the absolute regional effects, but to show the relative impacts of transport interventions. However strong the time restrictions might be, the ranking of the scenarios is in general not changed. With increasing time budget the effects of the construction of motorable tracks (Scenario 3) are gaining compared to the transport avoiding measures (Scenario 4).

[23] Assumptions: 2.3 persons per household, no labour on Sundays.
The time budget of a comparable European household can be estimated as follows:
2.3 persons * 240 working days * (8 hours work/day + 1 hour transport to/from work) ≈ 5,000 hours/a.

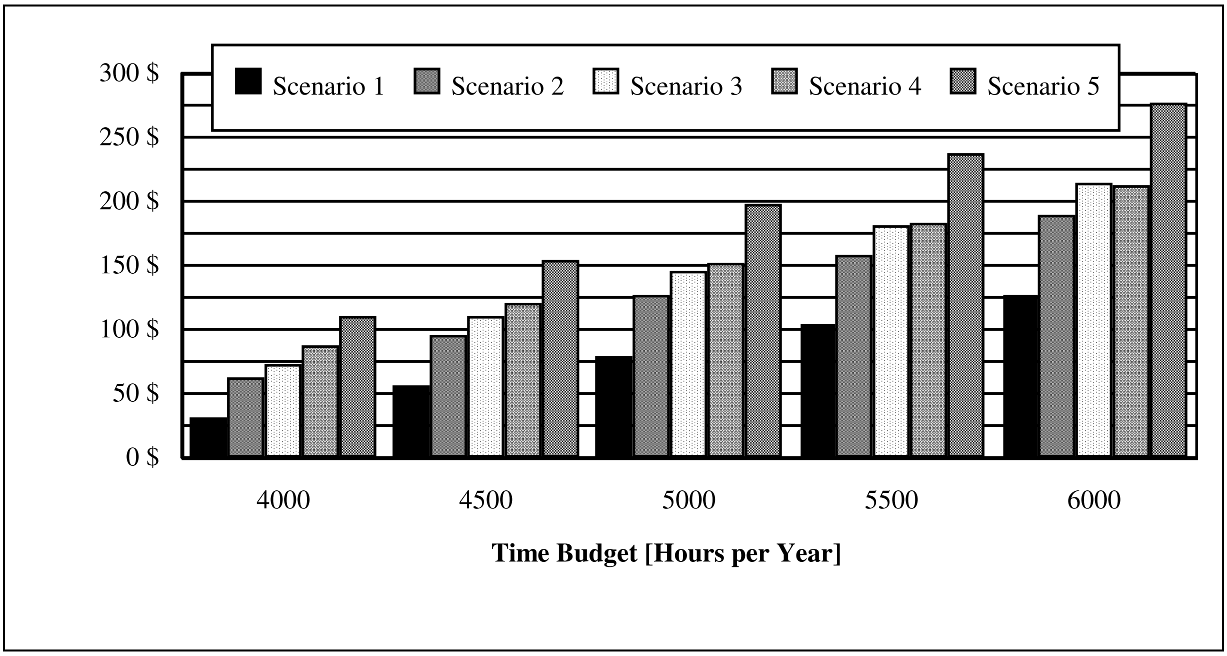

Fig. 5.4-1 Change of disposable income under different time constraints.

While the model used annual time limits in reality seasonal variations occur, which might set stronger restrictions than simulated in the model. The variation of the time requirements are examined for the last year of the simulation period (year 20). Fig. 5.4-2 shows the annual variation of the monthly time requirements per household for labour in the fields (Curve 1) and for all transport activities (Curve 2) in Scenario 2. During most of the year more time is used for transport than for labour. The agricultural calendar causes an uneven distribution of the annual time requirements; time restrictions occur especially during harvesting periods, when the crops have to be transported to the marketing places[24] (curve 3). The labour time and the time for the trips to the fields (curve 4) do not vary as strongly as the total time needed for transport purposes.

Fig. 5.4-3 plots the total time per person and day used for transport and labour in the fields in every scenario. Scenario 1 has the strongest variation of time needs. Especially during the harvesting periods the long walking trips to the external market are causing high time requirements, which in June nearly reach 9 hours per day. The creation of motorised access to every village in Scenario 3 reduces the annual variations of the time exigency, which ranges only between 3.5 and 7.8 hours per day. The motorised access on the tracks cuts off the peak transport loads by shortening the trips to the marketing points

[24] The annual time distribution was achieved by combining the agricultural calendar (BARWELL / MALMBERG CALVO 1987, pp 52) with the results from the field study. Because no data on the annual variation of the marketing trips were collected, it is assumed that the households market their products just after harvesting them. Missing storage facilities and risk reduction from pest damage are the main reasons for this behaviour.

during harvesting periods. The scenarios 2, 4 and 5 range in-between the scenarios 1 and 3.

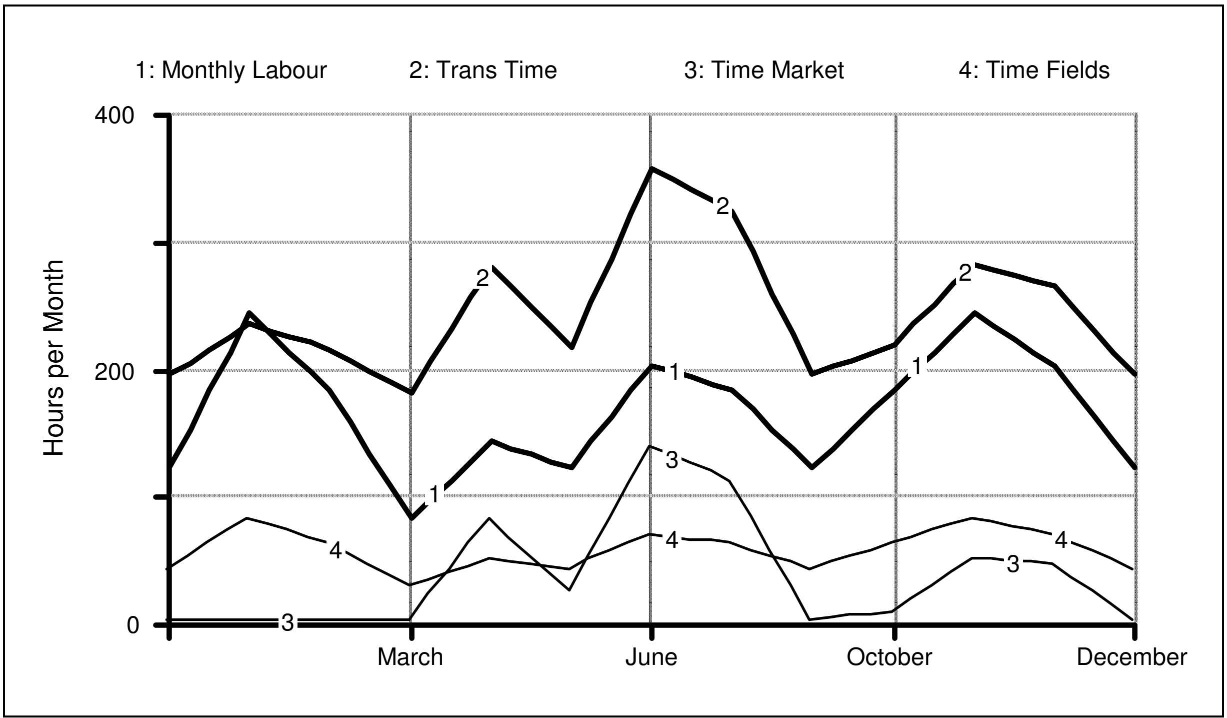

Fig. 5.4-2 Annual variation of the transport and labour time in Scenario 2

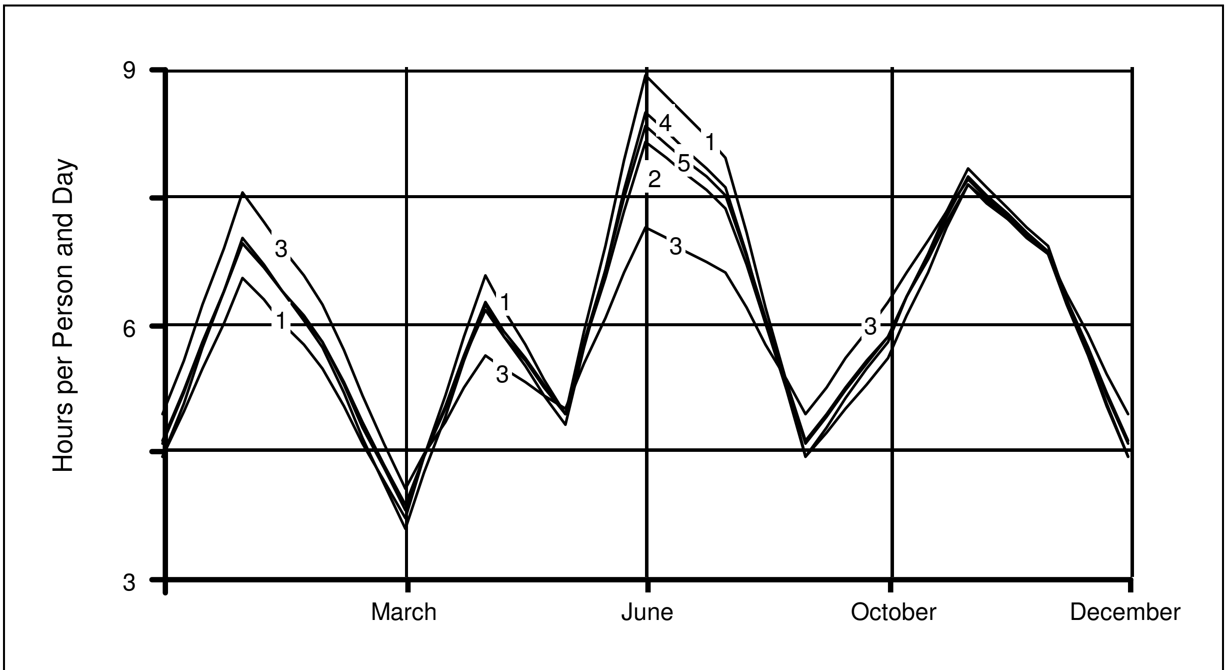

Fig. 5.4-3 Daily time requirements by labour and transport per person in all scenarios

The introduction of IMT has remarkable effects: even though households in Scenario 5 market 1.2 tons more crops than farmers in Scenario 2, the daily transport time during peak marketing seasons only differs by 10 minutes. The use of IMT reduces the number of trips needed for the evacuation of crops from the fields and for their transport to the markets. The simulation explains the intensive use of the IMT during the harvesting periods observed in Matamba. The construction of motorable tracks has the strongest effects regarding the time requirements during the harvesting season in June and July.

5.5 How can Road Investments and Maintenance Be Financed?

There is no doubt that roads and IMT are crucial for the regional development of peripheral regions, but someone has got to pay! One of the most salient features of the transport system in most Sub Saharan African Countries is the lack of maintenance of the existing road network[25]. The main reason is the lack of funds, which make adequate maintenance of the whole network impossible. This chapter will try to assess the possibility to finance the rural roads locally.

THERKILDSEN/SEMBOYA (1992) conducted research on the resource mobilisation in rural districts of Tanzania. The financial situation is so bad that most local infrastructures such as primary education, health services and rural roads are collapsing. The village and local governments have not been successful in raising their own revenues. The country wide collection ratio[26] of 50 % for the local governments can be explained by the poor administrative endowment and their bad performance. Declining revenues of the financial administration were related to corruption, mismanagement and wastage (p. 1103). The village government revenues stem from a share of the per capita development tax. These local revenues are earmarked for investment purposes and cannot be used for recurrent expenditures to maintain the local services. Due to the bad quality of theses services[27] people are reluctant to pay the development tax. In the long run the central government will not be able to solve the financial crisis of the districts and village governments. It is doubtful as well that the international donors would be willing to give long term subsidies for the recurrent district budgets.

In Tanzania many villagers had to participate in unpaid self help activities. THERKILDSEN/ SEMBOYA report that every village has 4-5 Self Help Projects and on top of that annually every person works 10-15 days only for road maintenance. JENNINGS (1992, pp 32) states that women accounted for 80 % of the Self Help activities of the MIRTP, which, despite the potential benefits, "substantially increased the workload of women"[28] and "seriously undermined the agricultural production". The unequal participation of the villagers is another point of criticism. The example of the Matamba-Chimala road (Box 5-1) shows

[25] Compare Chapter 2.4.3.

[26] Ratio between actual tax collection and potential tax revenue.

[27] For further reading see EDLING / FISCHER (1991).

[28] JENNINGS estimates the workload at more than 20 hours per week.

that the unpaid Self Help labour is often related to economic inefficiencies. Therefore in Matamba a local tax was preferred to Self Help labour. It can be argued in favour of the Self Help projects that they reduce the possibility of public funds being misused.

Box 5-1: Self Help Maintenance of the Matamba-Chimala Road

The rehabilitation of the Matamba-Chimala Road was initiated by the Matamba Ward as a Self Help project. The Self Help labour entailed a lot of economic inefficiencies like long walks from the homesteads to the escarpment (3 hours one way), which had to be undertaken every day. On top of that the work had to be done during periods where agricultural activities were required. The high opportunity costs of agricultural labour was the main reason why the Matamba Ward Council decided to raise a local road tax in order to pay hired labour, which was to be used instead of Self Help Labour. A tax of 40 ¢ per able bodied person was planned. In 1994 only one sixth of the expected revenue could be collected. Administrative changes were given as the reason for the poor collection ratio. The missing funds were partly replaced by the Lutheran church, but still the maintenance work could not be done properly by the end of the rainy season. Nevertheless the road was still in a "good" condition according to the judgement of a district council driver.

A road toll station was installed in Matamba, where all vehicles have to pass.

A means to solve the financial problems of the communities could be the levy of user charges, which should be designed as follows:

- The charges should cover the full investment and maintenance cost and the costs for the collection of the charges,
- the revenues should be earmarked for a special purpose,
- the charges should be simple and inexpensive to collect,
- users pay only according to their utilisation, and
- a locally elected commitee or institution should control the adequate use of the revenues.

Nowadays user charges are already collected for the grinding mills by the churches who operate the mills. It can be doubted whether these charges cover the full costs of the mills[29]. Water supply is given free of charge. Nevertheless it would be possible to collect a charge for the provision of clean water, which at least covers the maintenance costs[30]. The construction and maintenance of foot-

[29] Often the prices are set not by economic but by social deliberations. The sustainability of the projects can be only secured by continuous external aid from the international donors.

[30] In the case of Makete, where piped water systems were installed maintenance could be covered by $ 4.6 per household and year. The total investment costs (10 years writing off,

paths is so cheap, that it makes no sense to install a toll station. As long as the path is only used by one village, the maintenance can be conducted using self help labour. The willingness to participate in Self Help activities declines as soon as users from other villages walk on the path without participating in the maintenance. In this case it should be possible to collect the charge together with the market tax at the marketing place.

Since July 1991 in Tanzania a national road fund has existed, into which a share of the fuel tax (10 ¢/litre) is paid in order to secure the maintenance of the road system. 20 % of the road fund is reserved for rural roads. Experience from the Makete District shows that these funds are not sufficient to maintain the road network[31]. The district council in Makete does not pay the communities regularly in order to secure the maintenance of the transport network, but funds are released "according to the requirements". In some cases the spheres of responsibility between district council and regional engineer are not clearly delimited; the missing maintenance of the regional roads forced the district council to use their scarce funds to maintain regional roads in order to keep the external communication working. Often local roads, which were maintained by the village or ward authorities were in better condition than regional and district roads. The basic feature of successful systems seems to be the local interest in a road and the efficient control and enforcement of its maintenance.

Scenario	**User charge per ton**	**Budget Road Fund**	**Reduction Disposable Income***
	$/ton	$	%
1	0.00	0	-
2	4.01	178,000	- 3.6 %
3	9.27	479,000	- 9.7 %
4	3.42	181,000	- 3.4 %
5	2.62	185,000	- 3.8 %
* User charges for water supply not included			

Tab. 5.5-1 Road user charges

The collection of road user charges can be a solution to the above mentioned financial problems. In the case of the model region, which has spatial structures similar to Matamba, a road toll station could be installed at village B (Fig. 5.3-1), where all the incoming and outgoing traffic has to pass. Here a road tax can be levied according to the weight transported. A locally elected committee could take over the control of the revenues and the maintenance works. The following assumptions are taken:

- The construction of the road is financed by a credit (real interest rate of 8 %).
- Annual maintenance is paid by this fund.
- Road user charges are paid into the fund.

interest rate 0 %) would be too expensive for the households ($ 40/year). Wells and hand pumps, which are much cheaper would imply annual charges of $ 8.

31 The district network consists of 190 km of district roads and 500 km of feeder roads. In 1994 the district received $ 10,000 from the national road fund, which is 14 $/km. The funds were used to improve 20 km of roads and repair two bridges.

• The charges are designed in such a way that after 20 years the debt is completely repaid.

Tab. 5.5-1 shows the necessary charges to fulfil the above listed requirements. Scenario 2 and 4 make user charges of 3-4 $ per ton of exported products necessary. In Scenario 3 user charges of 9 $/ton would need to be raised, in order to finance the construction and maintenance of 140 km of local tracks. The donkeys in Scenario 5 have strong impacts on the market production; less than $ 3 per ton would have to be charged. It has to be mentioned, that if only the maintenance works are financed by the road fund, the whole system would be sustainable at 35 % of the named charges. The next column in Tab. 5.5-1 indicates the necessary initial budget of the road fund to finance construction, maintenance and interest. While all the scenarios range around $ 180,000 the initial budget for Scenario 3 amounts to $ 480,000.

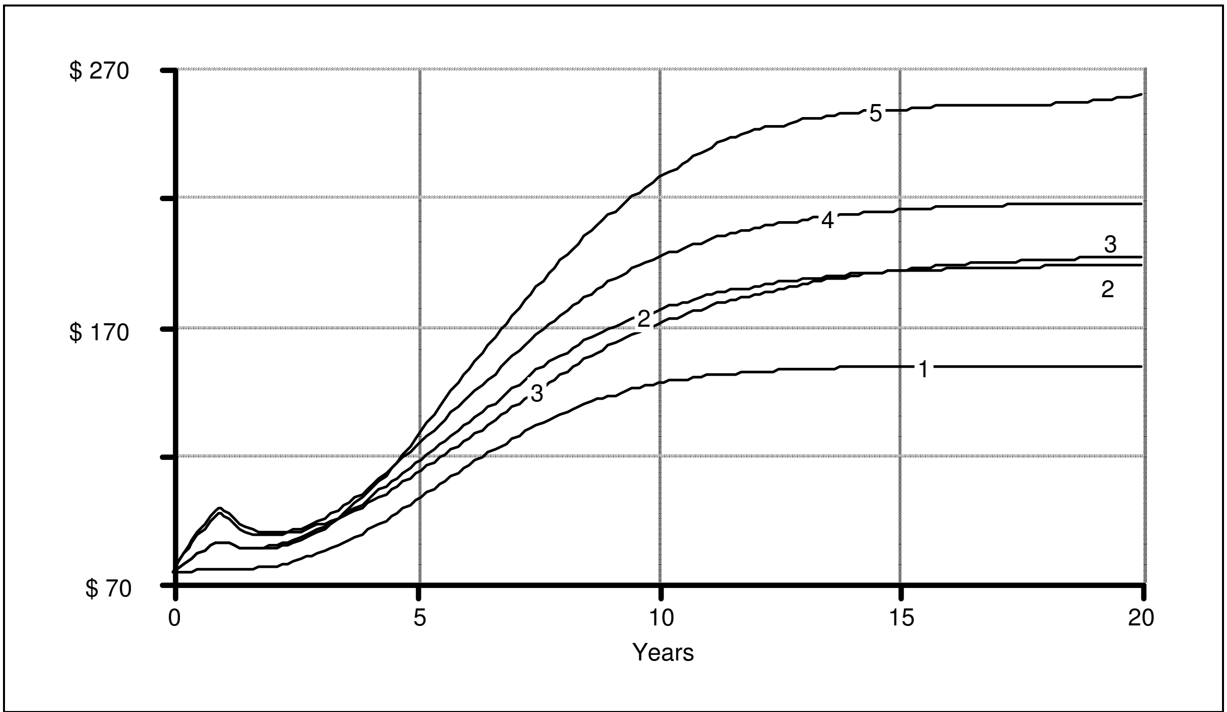

Fig. 5.5-1 Disposable income reduced by road user charges

It can be assumed, that the traders will completely pass on the road user charges to the farmers. Therefore producer prices will be reduced by the road charge and lead to a reduction of the household's disposable income, listed in the right column of Tab. 5.5-1. A general reduction in the disposable income of 4 % in the Scenarios 2, 4 and 5 and of 10 % in Scenario 3 can be stated. The development of the disposable income is plotted in Fig. 5.5-1, which shows that the households in Scenario 3 now have the same income as the households in Scenario 2 (compare Fig. 5.3-7). The question arises as to whether the producer prices in Scenario 3 have reached a level, where the farmers react by producing smaller quantities and whether they are willing to pay this high price for the non-monetary benefits.

5.6 Conclusions

In this chapter the empirical evidence observed in Makete District is used to built a model, which simulates the effects of rural transport interventions using a systems dynamic approach. An ideal region was assumed, which is initially completely isolated from external markets. Over a period of 20 years five scenarios assess the effects of different transport interventions, which are listed in Tab. 5.6-1. The main restrictions are the limited time budget of the households, the availability of fertiliser and the access to credits.

Initially the model region is completely isolated and the agricultural production is used to satisfy the subsistence needs. The regional economy stagnates because the low internal demand is not able to generate a significant growth. This process is induced by the construction of a **Footpath**, which gives access to an external market. Because the market is still within walking distance some villages begin to increase their production and sell crops outside the region. The disposable income increases on average at annually 3.8 %. The low construction and maintenance costs make it possible to obtain a high rate of return[32]. The rate seems to be quite elevated, but the initial situation with an assumed complete isolation of the region has to be taken into account[33]. It can nevertheless be stated that the production is very quickly restricted by the limited time requirements for the long walking trips to the external market and the lack of fertiliser, which is not available without motorised access. The construction of a footpath seems to be an efficient transport intervention, if

- the region has no motorised access,
- markets are within walking distance,
- funds available for road construction are not sufficient or
- a risk averse investment strategy is preferred.

The construction of a low cost **Feeder Road** to the regional centre reduces the time requirements for the evacuation of crops and makes fertiliser available, both of which cause a stronger increase in production than in the previous scenario. Increasing trips to the fields and to the collection points reduce the disposable time budget and set limits to the production. Income increases annually by 5.2 %. If a low cost road is built the rate of return amounts to 56 %. Of course here as well as in the previous scenario the good initial conditions favour a high rate of return. The construction of a feeder road is the basis for all the

[32] The economic rate of return compares investment and maintenance costs with the benefits from the increased disposable income. In the case of scenario 5 and 6 the IMT and the Transport Fund are included.

[33] Probably the model overestimated the production increase for the footpath scenario, because no functional relation between distance to the market and market production could be implemented. The long walking distance would probably set stronger restrictions than in the other scenarios.

following scenarios and the effects always have to be regarded in relation to this scenario.

Scen-ario	Main Features	Costs		Without User Charges		With User Charges	
		Initial Invest-ments *	Annual Mainte-nance	Annual Income Growth	Economic Rate of Return**	User Charges	Reduction Disposable Income***
		$ / Inhabitant		%	%	$/ton	%
1	Footpath	0.46	0.03	3.8 %	114 %	0.00	-
2	Feeder Road	6.00	0.34	5.2 %	56 %	4.01	- 3.6 %
3	Feeder Road + Local Tracks	15.51	0.54	5.6 %	37 %	9.27	- 9.7 %
4	Feeder Road + Wells + Stoves	23.07	0.49	5.8 %	32 %	3.42	- 3.4 %
5	IMT Fund + Feeder Road	15.00	0.34	6.7 %	58 %	2.62	- 3.8 %
6	Succession of interventions	Not comparable		7.5 %	102 %	6.11	- 7.1 %

* The initial endowment of the IMT Fund is added to the total investments for road construction
** Benefits: change of Disposable Income,
Costs: investments, maintenance, IMT Fund, Transport Fund
*** Compared to the same scenario without user charges.
Scenario 4 and 6: user charges for piped water supply not included.

Tab. 5.6-1 Salient results of the scenarios

The third scenario tries to reduce the time constraints by supplying every village with a motorised access. The construction of a network of **Motorable Tracks** combined with the above described feeder road causes a reduction in the transport to markets and gives rise to another increase of production. The disposable income grows by annually 5.6 %, which is faster than in the previous scenario, but due to the high investment and maintenance costs the rate of return reaches only 37 %. Of course the roads would have other non-economic impacts, which cannot be monetarised here: reduced drudgery for market trips, access for ambulances and mobile health services.

In the fourth scenario the effects of **Transport Avoiding Measures** are simulated. All villages receive wells, water pumps and low consumption stoves, which reduce the time budget for subsistence transport. Production reaches the same level as in the previous local-track-scenario, but the lower VOC cause a slightly higher disposable income. The high investment costs reduce the rate of return to 32 %, which is below that of the previous scenario[34].

The biggest effects after the construction of a feeder road can be achieved by the promotion of **Donkeys and Bicycles**. The main reason why farmers are nowadays not purchasing the IMT is the high price; without any access to cred-

[34] If instead of the rate of return the net present values was compared, then only a depreciation rate higher than 4.6 % would favour the tracks scenario.

its only 15 % of the households in the scenario 2 would be able to purchase an IMT. Therefore a revolving credit fund for the purchase of IMT is implemented. A credit coverage of 75 % would, after 20 years, give 62 % of the households access to IMT. The IMT have two general effects: they reduce the transport time and they increase the productivity from decreasing to increasing returns to scale. These effects induce a strong growth in production. The growth of the disposable income (6.7 % p.a) exceeds the growth of all the previous scenarios. The rate of return can be estimated at 58 %. The model shows, that the purchase of an IMT even with a real interest rate of 12 % and a repayment within 5 years can be very profitable for the farmers. One of the main problems of these types of funds are the high overhead costs and the low repayment morale. Even if it is assumed that only 80 % of the credits are paid back, the fund will grow during the simulation period and reach positive values after 12 years if no credits are distributed to replace old IMT. At the end of the modelling period a surplus of more than $ 16,000 can be accumulated, which could be used for other development activities or to finance the high overhead costs of the credit system. It seems to be sensible to design the credit system primarily for women in the form of a revolving fund. The West African savings clubs, called 'Tontine', could be an appropriate institution to organise distribution of credits and collection of the debt service payments.

Someone has got to pay! In consideration of the desperate public financial situation in many Sub-Saharan African countries there is little hope that new rural roads can be financed by the recurrent budgets. A step towards a sustainable system could be taken if village governments, wards or districts were permitted to levy road user charges at special road toll stations. The model assumes that revenues are collected in a road fund, which has the goal of repaying the full investment, maintenance and credit costs (real interest rate 8%) of the project after 20 years . The user charges are listed in column 5 of Tab. 5.6-1. It is assumed that the user charges reduce the producer prices and therefore have an impact on the disposable income (column 6). A complete cost coverage of a feeder road would imply road user charges of $ 4 per ton and a reduction of the disposable income of 4 %. In the case of the construction of motorised track access to all villages user charges of 9 $/ton would have to be levied. This would reduce the disposable income of the households by 10 %. The income would reach the same level as if only a feeder road to the regional centre was constructed. The question arises as to whether the farmers are willing to pay this price for the reduced market transport and the non-monetary effects of the tracks.

An **Integrated Transport Approach** favours a combination of the above mentioned transport interventions as proposed in Fig. 5.6-1. The measures are financed with a Regional Transport Fund which is a combination of the Credit Fund for IMT and the Road Fund. The fund will be financed by an international credit with 8 % interest rate. In the initial phase, when the region is not accessible by motor vehicles a footpath to an external market is improved and credits are distributed for the purchase of IMT. If the farmers respond after a period of three years by increasing their market production, a feeder road to the regional centre is constructed. After six years of simulation the total debt reaches its maximum at $ 9.3 per inhabitant. A road user charge comprising 8 % of the producer price is levied on the exported products. The growing market production will enable the road users to repay the debt until year 9. Now the market production exceeds three tons and transport constraints hamper its further growth. After another two years enough user charges are collected to finance the construction of motorable tracks to every village. This investment entails another production expansion and the fund fills up faster in order to finance transport avoiding measures in the year 16. After 20 years the annual market production exceeds 4.2 t and the disposable income reaches $ 290, which implies an annual increase of 7.1 %. The income seems to be still very low, but it has to be compared to the reality in Makete, where in 1994 the revenues amounted to less than $ 80.

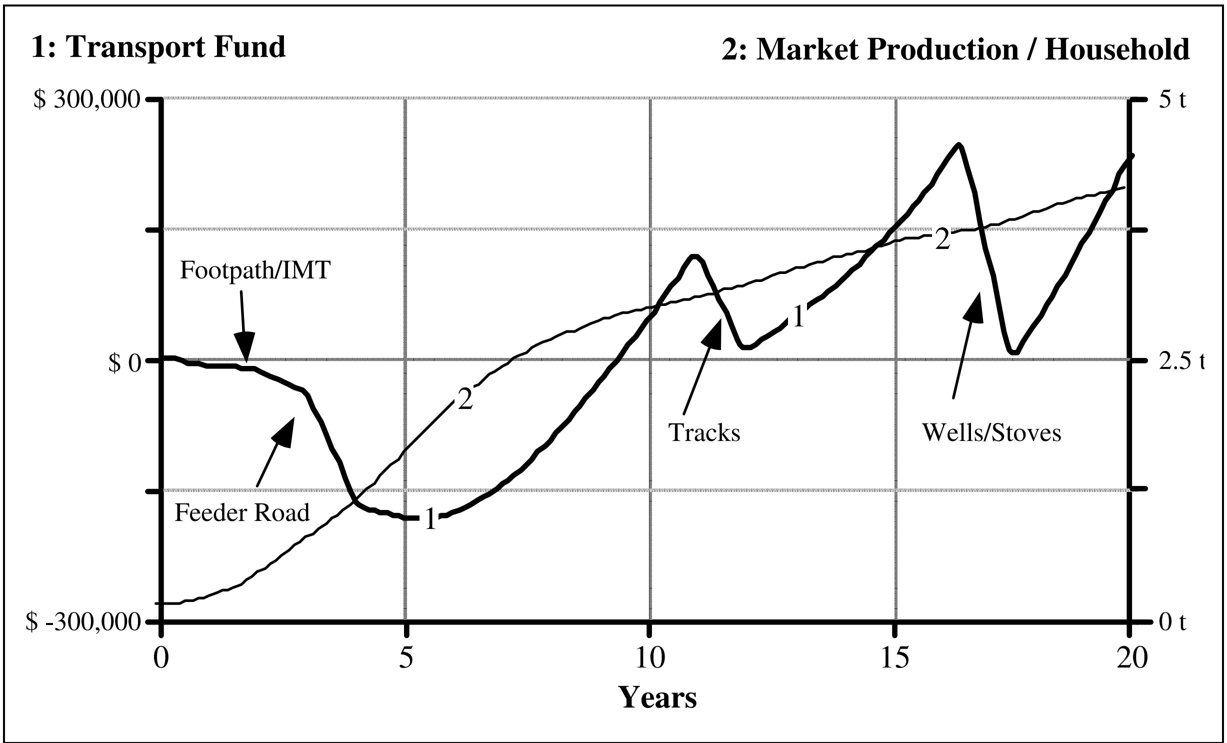

Fig. 5.6-1 Succession of various transport interventions (Scenario 6)

The model also shows, that with increasing production the investments have smaller productive effects due to decreasing returns to scale with the given production technology. At the end of the simulation period the invention of new agrarian technologies, like the use of ploughs with animal traction, high yielding varieties or irrigation schemes might entail a change of the production function. A further production increase necessitates another change of the transport technology, because the evacuation of crops can only be managed with animal drawn carts or small motor vehicles.