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# Economic impact of forest use at regional level: A case study in the Amazon forest margins, Brazil

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## Abstract
Agricultural production in the forest margins of the Amazon, in the past, were often shaped by colonization programs of the Brazilian Government. Farmers were settled in marginal regions to enable exploitation of new land for crop and livestock production. In addition to this, an important wood processing industry developed in the region. Recent figures show that deforestation rates do not drop, meaning that the restrictive laws are not effective. This paper reports on results from a study on the interaction between local farming systems and the wood processing industry at a regional level. In particular, it assesses the economic impact of different strategies on these sectors. Economic impact of forest use is tested applying an optimisation model which maximizes the regional income and optimises the resource allocation. Results show that total protection of the Amazonian rainforest would lead to disappearance of the wood processing industry in the region. This would also cause a decrease of regional income compared to the actual situation. An unrealistic external payment of more than 500US$/hectare forest/year could compensate these losses, creating problems of allocation and dependency. An increase of farmers income could only be attained by agricultural intensification of the arable land. The introduction of a sustainable forest management system would have positive economic impact at regional level. Both sectors would profit from such a strategy. Depending on the sustainable timber yield per ha and year the regional income would gain from.

**Keywords:** Amazon, Forest margin, Farming, Forestry, Impact analysis

## Introduction
The Amazon Rainforest is the largest related forest area in the world. An increasing demand for arable land causes the expansion of an agricultural frontier into the natural forest resources. Forest clearing with transformation into agricultural land leads to an enormous reduction of the forest area and the agricultural frontier moves slowly, but continuously from the savannah into the deeper Amazon rainforest. The Brazilian government, in the past, set incentives to colonise the savannah and the forest margins to reduce migration pressure from the overpopulated urban areas. Due to these incentives farmers from other Brazilian areas were settled to a large extend in these sensitive areas. The agricultural production of the developing farms was established by clearing the forests and expanding the arable land. In addition to this, an important wood processing industry developed in the region.
Due to private land-ownership of the land resources, the forest clearing is an ongoing problem and because of recent national and international pressure, the Brazilian government introduced laws aiming on a reduction of the extinction of natural forests. Actual figures show that deforestation rates do not drop, meaning that the restrictive laws are not effective.
This paper reports on results from a study on the interaction between the local farming system and the wood processing industry at a regional level. In particular, it assesses the economic impact of different strategies on these sectors in the municipality Sinop in the North of Mato Grosso.

The study is part of the project "Dynamics and Sustainability of Farming and Regional Systems in the South American Savannas" where different institutions are involved into research. The project knowledge partnership consists of the University of Hohenheim (Germany), the University of Uberlandia, the University of Cuiaba (both Brazilian), the Research Center CIAT in Colombia and EMPRAPA, the national agricultural research centre of Brazil.

## Problems and objectives

Due to the fact of governmental colonization in the Amazon forest margins with special support of farming activities, a major conflict between agriculture and forestry occurs. Predominant farming systems clear the forests to a large extend for agricultural production, without any sustainable respect to the forest resources. Forest cover of 100% before colonization has been changed in the last 25 years to ca. 50% forest area and 50% arable land. In the remaining forest resources all valuable timber is nowadays exploited. Because of the availability of valuable timber, a strong wood processing sector developed next to the farming sector. The industry demands timber extracted from the Amazon forest. After exploiting and processing the valuable timber of the forests, the thinned secondary forests can be cleared for agricultural production. Therefore the forest margins still show a high rate of deforestation. The objectives of the study are oriented at the mentioned problems and are as follows:

- To examine the past and current development of farming and wood processing in the forest margins
- To understand the interrelations between farming and wood processing
- To understand the impact of the farming and wood processing sector on the decline of the forest area
- To investigate potentialities of forest use at regional level

The primary data was collected from the two dominant sectors in the region, the farming and wood processing sectors. Both activities contribute a major part to the regional economic success. First of all the analyses of farming and wood processing activities should give insights in the dependencies and interrelations between the two sector. Furthermore future development potentials will be assessed using a regional model.

## Development in the forest margins

In the past the Brazilian government set incentives to colonise the forest margins to intercept the increasing population in the urban centres of the country. In the case of Sinop, Northern Mato Grosso, a private colonization company purchased a large area of forest margin land from the government. The area was totally covered with natural forests and before settlement the land needed to be measured and divided into different plots. After the construction of basic infrastructure at the beginnings of 1970 the settlement of farmers started. To begin with farming the forest needed to be cleared and transformed into arable land. Due to the availability of valuable timber in the forest resources, wood processing enterprises established simultaneously, to extract and process the timber. In some cases farmers started next to agricultural activities a wood processing enterprise, but basically both sectors developed complementary. Nowadays they contribute together more than 60% to the regional economy. The farmers exploited the valuable timber from their forests in a selective way and sold it to the wood processing industry. This input facilitated partly the investment in total forest clearing and conversion into arable land.

In the centre of the region is the City, where the major part of the wood processing industry and 90% of the regional population is located. Considering no population at beginning of colonization, 70,000 inhabitants are living in the area at date of data collection (Dec. 1998). This tremendous population increase shows the importance of the two sectors on the regional development and impact on the forest resources. The total amount of sawmills could not be

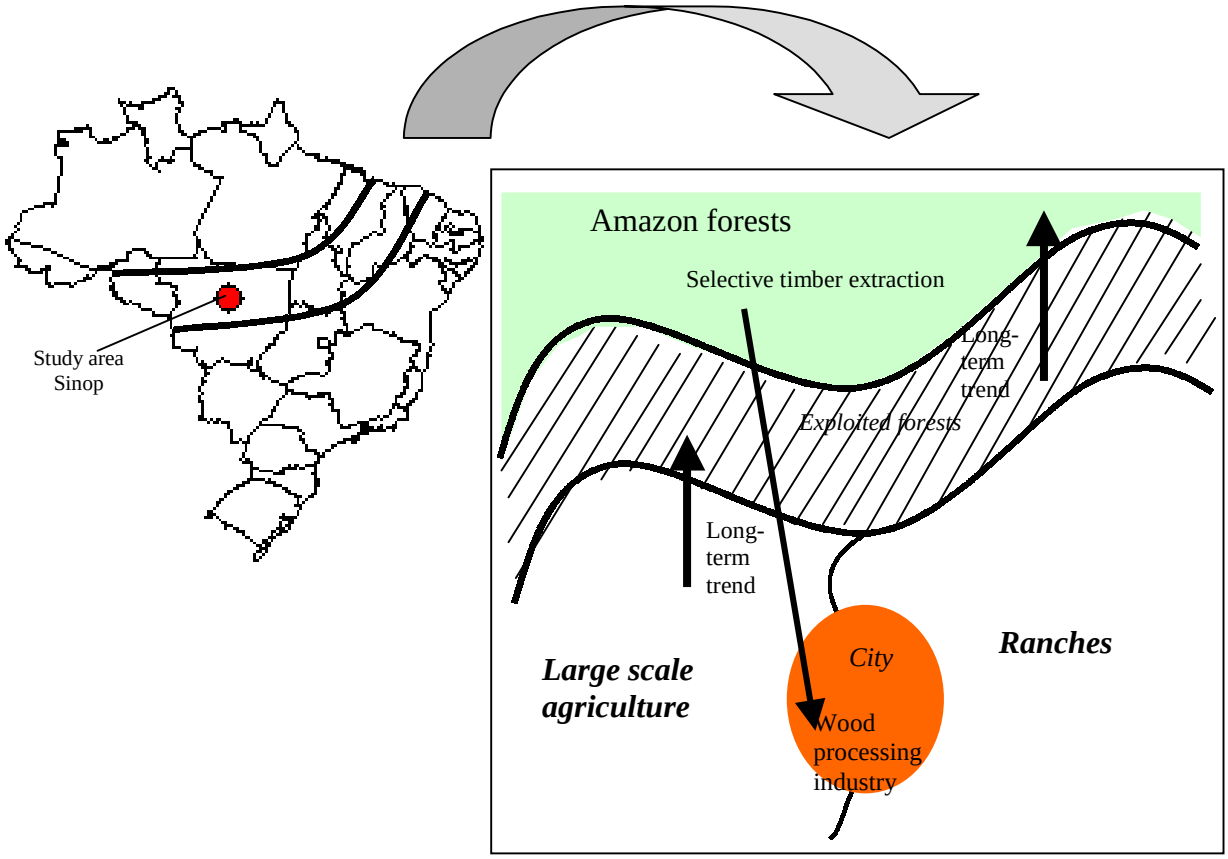
captured exactly, but interviewed key-person provided the figure of ca. 200 processing enterprises. The average of timber processing is 6,238$m^3$ per year and enterprise and results to a total of 1,247,600$m^3$ per year in the study area. The main finished products are construction wood, panels and boards. An average employment of an enterprise is 15 workers and is therefore an important source for employment in the region.
The agricultural sector is also a source for employment, but not to the same extend as the sawmills. An average employment of a farm is ca. 4 persons additionally to the family labour, with a high focus on seasonal labour. Results of the farm analyses show that in the study area large scale agriculture and ranching are the common farming activities. Table 1 show the high importance of medium and large scale farming in the region.

Table 1. Land ownership and the Number of farms in Sinop, Northern Mato-Grosso, 1998

| Farm classification | Owner(no.) | (% owner) | Sum area | (% area) |
|---|---|---|---|---|
| Small scale (< 60ha) | 283 | (42.50%) | 5215 | (3.11%) |
| Medium scale (61-1000ha) | 343 | (51.50%) | 90174 | (53.73%) |
| Large scale (>1000ha) | 40 | (6.00%) | 72448 | (43.17%) |
| **Total** | 666 | (100.00%) | 167837 | (100.00%) |

A majority in numbers and land size is given in the group of medium scale farms. The Average farm size in the study area is 626ha, where 324ha is in forest, 180ha are for agricultural production, 120ha for ranching and the rest are in use of perennial crops (e.g. latex, fruits, etc.). An interesting figure is the forest area, with 50% of the total area. From the start of settlement up to now the farms decreased in general their forest cover of originally 100% to 50%. Here we see a very important linkage between agriculture and forestry. Forest use, in the past, were seen from the farmers as a source of timber to sell, but mainly as potential farm land, which had to be cleared and transformed. Forestry therefore is dependent to a large extend on decision-making of the farmers.
In general the past and current development in the forest margins can be extrapolated as follows (see also figure 1):
After establishing the infrastructure of the region the settlers bought their land from the colonization company and hence all land of the region is in private ownership. Before starting with farming the valuable timber of the forests were exploited and afterwards the area was cleared for agricultural production in the savannah. These exploited forests can be simply seen as a band between agricultural production in the savannah and the Amazon forests. The valuable timber of the exploited forest resources was extracted, transported to the wood processing industries, finished and sold to the urban centres of Brazil or exported to other countries. In general the process of exploiting the valuable timber of the natural forests with selective felling is followed by clearing the forests and transforming them into agricultural land. So the lasting demand of valuable timber from natural forests by the wood processing industry is a initial step into the closed forests and is in general followed by conversion into arable land. Sustainable forest management is not considered by the different groups, but local knowledge assume a sustainable use of the forests is possible.

Figure 1. The study area and the basic development in the forest margins




Due to national and international pressure to decrease deforestation the Brazilian government introduced laws to protect the natural forests. Legislation says that a land-owner owning more than 60ha total land must leave 50% of his land in stocked forests. This law concerns the most land-owners in the region. Furthermore such restrictive laws need control and in view of the limited capacity their successful implementation is doubtful. Apart from the ability to implement such laws, the increasing importance of the forest resources and their management are important for the regional development.

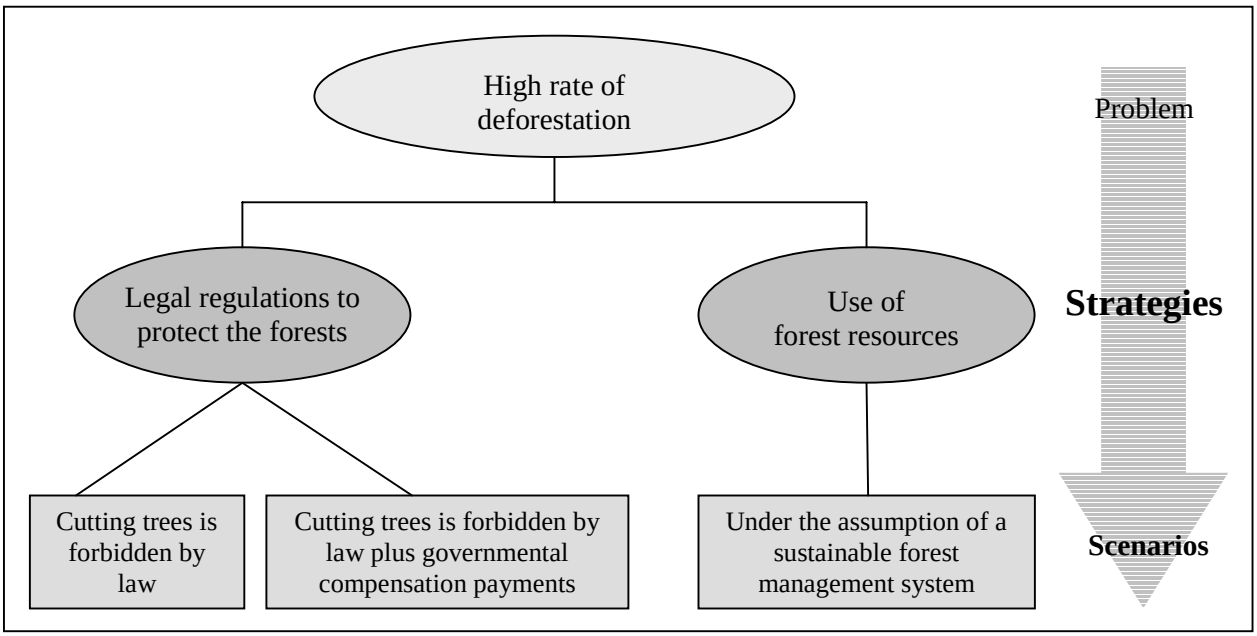
**Future development potentials**

The descriptive analyses of the past and current development of farming and wood processing in the forest margins opens a lot of questions about the future development. The impact of different future strategies can be quantified by modelling. After formulating the strategies, an appropriate model-matrix is constructed and the results of the application of different scenarios can be interpreted.

Strategies and scenarios of development

This chapter aims to define strategies to be tested and quantified in an optimisation model. Because of national and international pressure on a reduction of deforestation, high emphasis is given on strategies considering these issues. The definition of strategies should focus on the future development of the forest resources, with respect to the improvement of the regional conditions for farming and wood processing.

Figure 2. The different strategies to be tested in the regional model




In this study two strategies were tested to examine the economic impact of forest use:
One is the protection of the forests by legal regulation and the other one is the sustainable use of the forest resources. Forest protection by legal regulation is understood as a total protection of the forests where no cutting of trees is allowed. The regulations were applied for the total Amazon rainforest, assuming no more timber extraction will be possible after implementation. The strategy should quantify the impact of such a restriction on regional level. To support the land-owner for their lost profit from the forests the simulation of governmental compensation payments on different monetary levels will show the impact of subsidies for the protected forests. In regional terms the compensation payments should be used to support rural development of other sectors to intercept the monetary losses. The governmental compensation payments are assumed to reach the city council to promote regional development and enhance conditions for new profitable investments (e.g. ecotourism).
The strategy has the following scenarios: One scenario will simulate the introduction of legal restrictions, where no forest use is allowed. According to that, other scenarios will provide the impacts of different compensation payments, oriented at calculations from PEARCE et al., from a range of 100US$ up to 1000US$ per ha forest per year.
The second strategy is the introduction of appropriate forest management systems. As mentioned before the forest resources in the region are almost exploited at the moment. From different key-person interviews, local knowledge assume a natural re-growth in the exploited secondary forests has an average of one cubic metre per ha and year. The re-growth per ha and year are differing depending on the site, but due to homogeneous site conditions the assumption can be seen realistic. The re-growth assumption is verified by different silvicultural literature about tropical forests (e.g. LAMBRECHT, 1986).
Under the assumption of a sustainable production of one cubic metre per ha forest per year the second strategy will be tested. A sustainable use of the regional forest resources can have positive effects on the regional income. On the one hand farmers would have the possibility to sell their re-grown timber and have an additional income and on the other hand the timber providing of the wood processing industry can be guarantied in future and transportation costs can be reduced. Another scenario will test the regional impact of doubling timber yield per ha and year. Such a scenario could show if it is worth while to invest into forest management or if the competitiveness of agricultural production is too strong compared to the forest use.

All strategies are formulated to be tested at regional level including all farming and wood processing activities.

The regional model

Linear programming allows simultaneous incorporation of a set of activities subject to different constraints on the activities and solutions maximising an objective. These constraints are in the form of equations or inequalities in the model matrix. The limits of these constraints are at the "Right Hand Side" of the equations or inequalities, which restrict the different activities. For Solving the model matrix the XA Linear programming algorithm was used.
To integrate both, farming and wood processing activities, the model was formulated on regional level. In this case the so called "Gruppenhofmodell" is applied, where all regional farms are aggregated to one "Gruppenhof" (see also DOPPLER, 1973). As a special feature in this model the wood processing activities are integrated additional, considered as a commercial production, next to the farming. The objective function is intended to maximise the regional income which consists of farm income and wood processing profit. The regional income is maximised by maximising farming and wood processing production and minimising the costs of their productions.

The mathematical structure of the linear programming matrix is as follows:

$$Max: \quad Z = \sum_{i=1}^{n} Pl_i Xl_i - Cl_i Xl_i + \sum_{i=1}^{n} Ph_i Xh_i - Ch_i Xh_i$$

$$Subject\ to\ 1: \quad \sum_{j=1}^{m} Xl_i * a_{ij} \begin{matrix} \leq \\ = \\ \geq \end{matrix} b_j \qquad ,all\ \ j = 1\ to\ m$$

$$Subject\ to\ 2: \quad \sum_{j=1}^{m} Xh_i * a_{ij} \begin{matrix} \leq \\ = \\ \geq \end{matrix} b_j \qquad ,all\ \ j = 1\ to\ m$$

$$and: \quad Xl_i \geq 0 \ \wedge \ \ Xh_i \geq 0 \qquad ,all\ \ i = 1$$

where:

| | |
|---|---|
| Z | the objective function of maximising the total family income |
| $Xl_i$ | the farming activities i of all farms in the region |
| $Xh_i$ | the wood processing activities i of all sawmills in the region |
| n | the amount of all possible activities |
| $Cl_i$ | the costs per unit of the i input activity of the farms |
| $Pl_i$ | the price per unit of the i output activity of the farms |
| $Ch_i$ | the costs per unit of the i input activity of the sawmills |
| $Ph_i$ | the price per unit of the i output activity of the sawmills |
| $a_{ij}$ | the input-output coefficient or the required amount of resource j to produce one unit of the activity i |
| m | the available number of resources |
| $b_j$ | the amount of the j resource available |

The costs and prices of the activities in the objective function derive from the survey data and analyses of both sectors in 1998. All farming and wood processing activities and transactions between them are aggregated on regional level.
The constraints are aggregated values at regional level and represent the situation of the region in 1995-96 and 1998. This data derives partly from the survey and partly from an

analysis provided by the census data. The model has a comparative static character, where basic model results will be compared with the results of the applied strategy.
The basic model run provides an idea about the actual situation and is validated by the results from the analyses. Based on these results the strategies, discussed in the previous chapter, can be applied. An impact analysis is used to discuss the differences of the basic model results and the model results after the implementation of the strategies.

## Results

Due to the comparative-static character of the model, the basic model results will be discussed first. The interpretation of the basic model is used to compare it with the results of the applied strategies to assess their future impacts.

### Basic Model

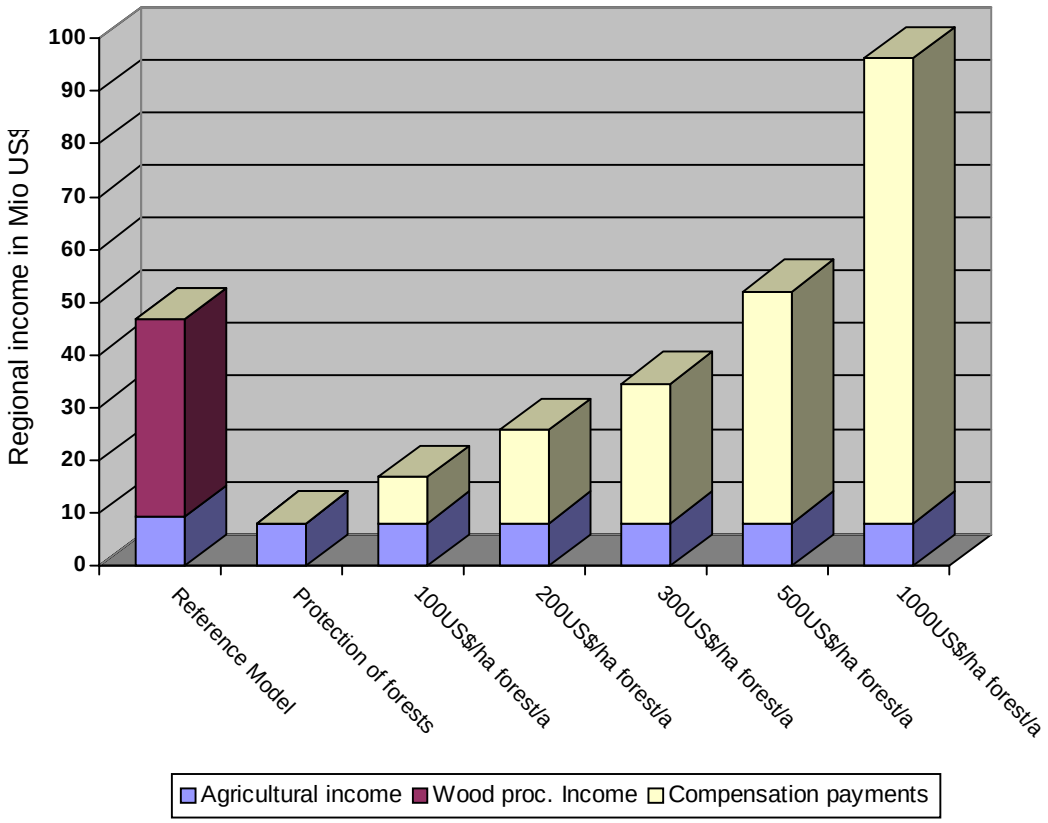
The basic model shows the farm and wood processing income, summed up to the regional income of both sectors at ca. 46 Mio. US$. Almost 80% of the regional income is generated by the wood processing industry, which shows the high economic influence of this sector on the regional development. The total land area in the model is 164,000ha, where 50% of the area is covered with forests, 15% is used for crop production and the rest of 35% is pasture land. From the original forest area, in the basic model run 4200 ha (4% of total land area) were cleared for crop production, but nothing was cleared for livestock production. The relevance of the different land resources are explained by the shadow prices and have the following order of values: crop land(1), pasture land(2) and forest land(3). These results show the low relevance of the forest resources under current conditions.
Next to the economic impact, the social impact of employment can also assessed by the model. In the basic model run the wood processing industry employs 4043 persons and the farming sector employs 537 persons, where family labour is not included. Compared to reality these figures are realistic and explain the importance of this issue for regional development.
In conclusion the basic model shows similar proportions as reality. Therefore the basic model with its results the linear programming matrix offers the possibility to apply the defined strategies and to analyse their impacts.

### The future impact of legal regulations to protect the forests

The first scenario run by the model was the protection of the forests by legal regulations, where no cutting of trees is allowed anymore. The strategy follows the approach of protectionists and should show the consequences on region level. To test the sensitivity of compensation payments, which try to intercept the losses, different levels of monetary subsidies were tested. The compensation payments are orientated at a cost-benefit-analyses from PEARCE et al. (1991), where carbon credits up to 1300US$ per ha Amazon rainforest per year were suggested.
First of all such a strategy would lead to the disappearance of the wood processing industry. If there is no supply of timber from the forest resources, there is no production base for wood processing. Therefore majority of the regional income in the basic model run would be cut down to 17%, compared to the results in the basic model. Also the farming sector would suffer from such a strategy, because forest clearing and transforming into arable land is forbidden and production increase by expansion of agricultural land is no longer possible. Deforestation on the other hand would be stopped. Independent of the practicability of this strategy the problem of deforestation would have been solved, but to which price?
Next to the decline in regional income, the scenario would have an enormous effect on the labour market, where employment of both sectors decline from 4580 in the basic model run down to 485 persons after applying the protection strategy. Both, decline in income and

employment show the impact of the scenario compared to the basic model run (see also figure 4)
Due to high losses in regional income and employment, a governmental compensation payment should intercept the losses and the money paid to the region should be seen to promote regional development in other sectors. A problem in this case is the allocation of payments. To simplify the interpretation it is assumed that the money will be paid to the city council, where the development of other sectors would be originated from.
Basically the scenarios with compensation payments for the protected forest resources show an increase of the regional income. A payment of 100US$ per ha forest per year would contribute to the regional income as much as the farm income, but the loss of the wood processing industry could not be compensated.

Figure 3. The future impact of legal regulations to protect the forests on regional income

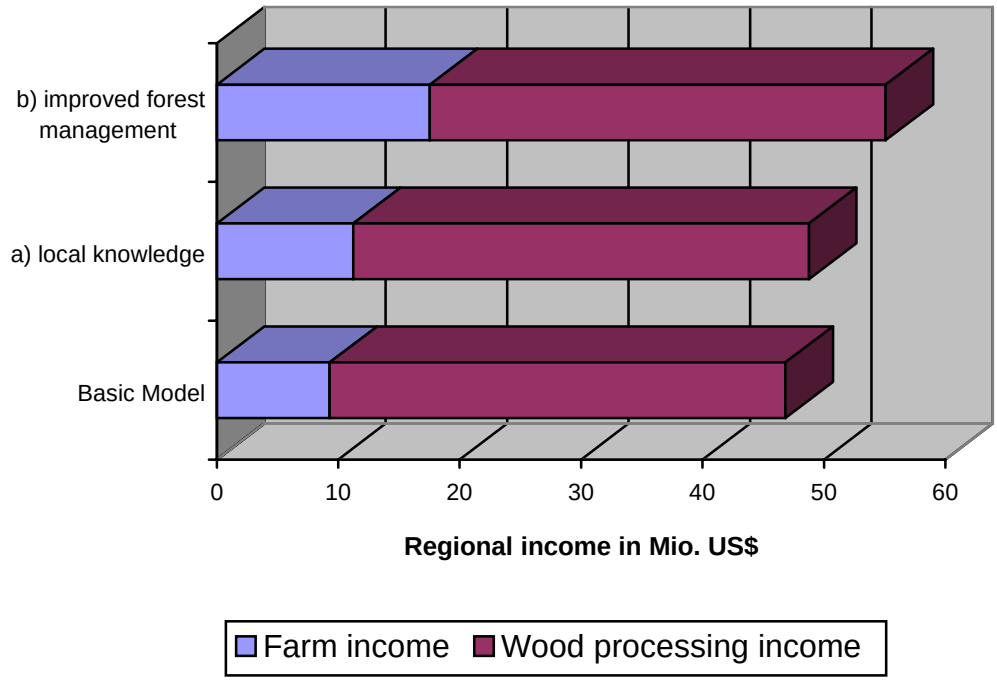



By increasing the compensation payment per ha forest the sensitivity of the payments can be tested. Basically the increase of payments would lead to an increase of the regional income. Therefore it is shown, that monetary payments could intercept the loss in regional income. On the other hand the impact on employment of the promotion of regional development could not be measured, but it can be assumed, that changes in employment would need time for implementation.
Interesting from the payment point of view is the threshold, when compensation payments can cover the monetary losses in regional income. The results show in this context, compensation payments of more than 500US$/ha forest/year could intercept the regional losses in income. In terms of cost-benefit calculations (see PEARCE et al., 1991) these figures seem to be at a justifiable level, but the implementation of such amounts of governmental payments can be seen as unrealistic.

Another effect of the strategy is that independent of compensation payments the farm income would stay at the same level in all model runs. The increase of farm income is under these conditions only possible by intensification of the available farm land.
It can be summarised, that a political protection of the regional forests by legislation, where no forest cuttings would be allowed anymore, would have tremendous impacts on the region. It is doubtful if the introduction of compensation payments on realistic levels can intercept the regional losses.

The future impact of forest resources use
The second strategy shows the impact of a forest management system, where forests are seen as productive land areas. The sustainable increment of harvestable timber per hectare and year in the regional forests on two different levels show interesting results on regional income and resources.
The first scenario with an assumed timber increment of one cubic metre per hectare and year, based on local knowledge, show a slight increase of the total regional income. Both sectors, farming and wood processing are still active and contribute to the regional economic success. The regional income would be increased up to almost 49 Mio US$, which is additional 4% compared to the basic model (see figure 4). Especially the farm income would gain from that strategy, because the farmers are the major forest owner in the region. Not included in figure 4, but also a result of the model runs is a decrease in forest clearing down to 50% of the forest area cleared for agricultural production in the basic model. The Impact of the strategy on employment on regional level would have a positive effect on hired labour in the farming systems. The farms could employ 6% more hired labour as in the basic model.
The wood processing industry would gain in the long run from such a strategy, because timber supply could be obtained and today's transportation costs would stay at least stable.

Figure 4. The future impact of a sustainable forest production on regional income




In a second scenario it is tested, which impact an improved forest management system, with an sustainable increment of two cubic metres of timber per ha and year, would have on the regional income. Compared to the basic model run and the first scenario with information of a sustainable yield, based on local knowledge, the regional income increases by 13% up to 55

Mio US$. Under these conditions especially the farmers as dominant forest owners would profit from their additional income from timber yield. As in the first scenario resources of employment would increase about 3% in the region, considering both sectors.
Deforested land area discussed as a major problem in the study area would decrease down to 50% of the rates in the basic model run. The tendency shows that the increase of a sustainable use of the forest resources, where permanent timber harvesting can be assumed and calculated, the attractivity of forest use instead of clearing increases. The implementation of this strategy supposes the availability of a sustainable forest management system, to increase timber yield. Under these conditions both sectors and therefore the region itself would profit from the forest use strategy, and an opportunity to deforestation is shown.

## Conclusion

According the objectives it can be concluded that the study area is a very sensitive area, where agriculture and forestry come together. The current development of the regional forest resources is not sustainable, because the forest area declines and the agricultural area expands. After exploiting the valuable timber from the forest farmers open up the forest areas and transform it into agricultural or pasture land. The examination of the agricultural and wood processing sectors show the heavy dependency of the region on the development on them.
To analyse the impact of the two dominant components on the regional economic success a regional optimisation model is applied.
A complete prohibition of forests use by legislation would lead to a disappearance of the wood processing industry and a major decline in regional income. Only unrealistic compensation payments could intercept the regional monetary losses, but the regional development would step, at least temporarily, into dependency on them. It would be difficult for the city council to promote an adequate rural development of other sectors, because the losses in regional income are more than 80%.
The impact of a sustainable forest use causes an increase in regional income and a decrease in deforestation. In this case both sectors could profit from the strategy in the short and long-term. Due to a lack of information in silvicutural systems to establish a sustainable forest management the implementation of the strategy is questionable, but it show that further research in that area is needed.
Future development in legislation will certainly protect the remaining forests, but forest use will still be possible. Therefore the relevance of forest resources in the region will have more emphasis on regional development compared to the past. In regional terms, forestry should get more emphasis, because results of the study show that a sustainable forest management of the regional resources would have a positive effect on regional development and on the objective to reduce deforestation.

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