# THE SYSTEM DYNAMI 3 MODEL FOR POLICY ANALYSIS OF THE FOREST INDUSTRY SYSTEM

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ABSTRACT

By means of the system dynamics theory and approach, A system dynamics model of the forest industry system for certain area is set up,and the future developing tendency of the forest industry system,under the conditions of various developing strategies and policies,is discussed quantitatively using the computer simulation based on the model.This model can provide scientific basis for making a long-term programme for the developing of the forest industry system.

## 1. FOREWORD

The forest industry is an important component of the national economy and plays a specific role in the development of the national economy.Since the founding of our new China, our country's forest industry has achieved a lot in comprehensive exploitation and utilization,and made a great contribution in national construction.However,the guiding ideology of management and utilization of forest industry, for a period of time,has some deviation,the forest exploitation and timber production has been emphasised;the reforestation and comprehensive utilization have been ignored.As a result the area of mature forest lands and exploitable resources have reduced repidly,and the proportion of the amounts of forest exploitation and reforestation is greatly imbalance.If the situation remains,it is impossible to achieve the goal of sustained-yield utilization of the forest resources.

The existing of the above problems influences,directly,the present production of forest industry and the forest resources for susrained-yield utilization.Meanwhile, the repid reduction of the forest resources also destroys the ecologic balance in some places. So we should think about the problem that how we can,in practice, produce more timber products,so as to give a full play of the forest fuction in adjusting and improving ecologic environment for public welfare,as well as meet the needs of our country's construction in timber and forest products,under the condition of keeping an everlasting resources for utilization and in view of the above cases and the characteristics of the forest production. This is a crucial problem that must be considered in the strategic studies and policy analyses for the future development of the forest industry system.

## 2. THE BASIC STRUCTURE OF THE MODEL OF THE FOREST INDUSTRY SYSTEM

The model of the forest industry system consists of three submodels:the analysis of forest resources growth and decline,capital construction and fund management.The submodel of the analysis of forest resources growth and decline can be further divided into three parts, reforestation,forest resources and timber production. The submodel of the capital construction embodies the comprehensive utilization of slash material,timber processing and fund for the capital construction.The last submodel is composed of funds accounting,forwarding profits to the state,state investments and loans.The relation between them is shown in figure 1.

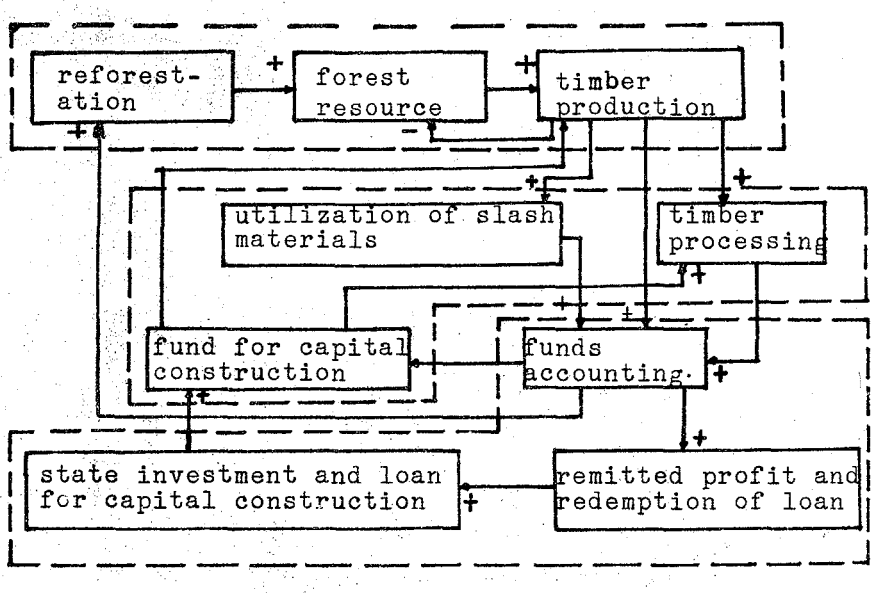


Figure 1 Basic structure of the model.

In the model,the reasons for that the demands for timber from the other trades are not considered are:

1) The forest resources in our country is extremely lacking,so the supply of timber products will be far from satisfying the demand of our country in a long period.

2) The system described by this model is a subsystem of providing timber products for the whole country.Under the extremely contradiction of supply and demand,the model can not simply produce in accordance with the amount of need.However it tries to produce as much products as possible,while ensuring a forest resources for sustained-yield utilization.This is one of the significant characteristic of the forest industry system.

By the analysis given above, we can see the resource-restricting factor is most important.

From the perspective of the system dynamic approach,the forest industry system shown in figure 1 is a dynamic feedback system which has the characteristic of non-linearity and multi-loops.The

external characteristic of the performance of this system is determined by a major loop.In this system,the loop composed of four parts which are in the sequence of reforestation--forest resource --timber production--funds accouting--reforestation,is a positive loop.This positive loop represents the procedure of the utilization and reproduction of the forest resources.When the loop plays the major role in the system(i.e when there is an appropriate proportion between cut and increment),the forest resources will tend to increase.Specifically,when the fund for reforestation grows, the newly-reforested land will expand and the level of forest-tending treatments will rise.So the forest resources will increase after a period of delay time.In turn,the increasing of the forest resources will lead to the growth of timber production,so that the more forest fund and the more profits can be expected,and finally the fund for reforestation and forest management will further increase.The above circling procedure is a fine circle of continously extended reproduction in the forest industry system.The loop composed of two parts,forest resources and timber production, in figure 1 is a negative feedback loop.This negative loop illustrates the interacting relation of the two parts.When this loop acts as the major loop,it will restrict the scale of forest production within the system,that is,when the rate of the timber production is higher than the growing rate of forest resources,the forest resources will show a tendency of decreaseing.Although the more fund for reforestation,achieved from timber production,can speed up the rate of reforestation for a time,the cut too much greater than forest increment can also exhaust the exploitable forest resources and cause the vicious circle in forest industry production,because the forest production circle is quite long(generally speaking,70--80 years from planting to felling under the present condition of management and production).The delay time from planting to felling will have significant influence on forest production.

In figure 1,there are another three positive feedback loops,which consist of,separately,(1) funds accounting--fund for capital construction--timber processing--funds accounting;(2) funds accounting--fund for capital construction--timber production--funds accounting;(3) funds accounting--fund for capital construction--utilization of slash materials--funds accounting.The three positive feedback loops illustrate the expanded reproduction procedure of the processing industry and logging industry.In this model the development of every industry discussed above has connection with investment and the effects of the investment.

## 3. THE MODEL OF FOREST INDUSTRY SYSTEM

The system dynamics model of the forest industry system embodies more than 500 variables,the basic causal relations among the major variables in the system are shown in figure 2.Because of the limitation of space,we have to focus on the details only about the submodel for the analysis of the growth-and-decline of forest resources.

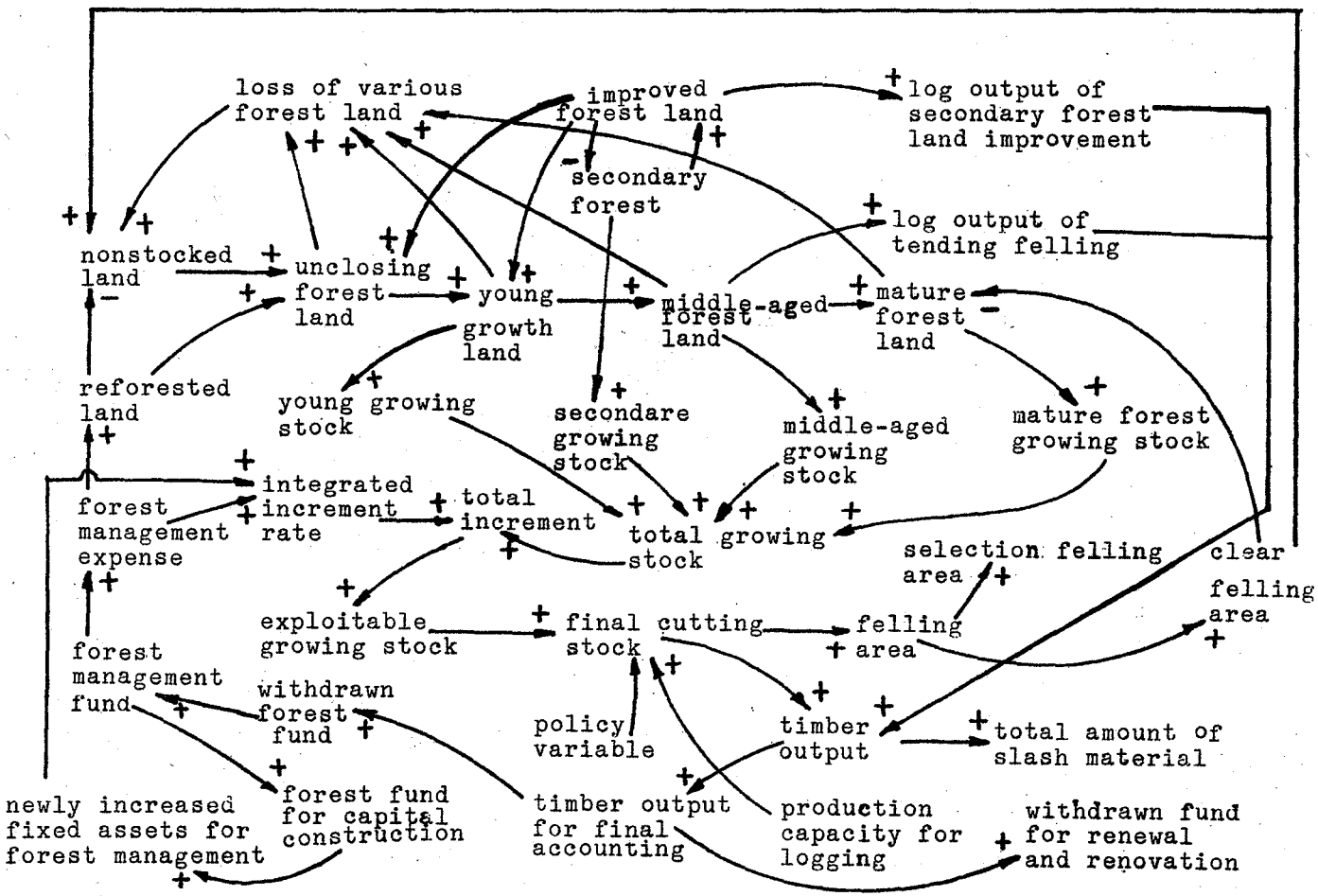


Figure 2 The Causal Relationships of the Major Variables
(Join the two figure 2 together.)

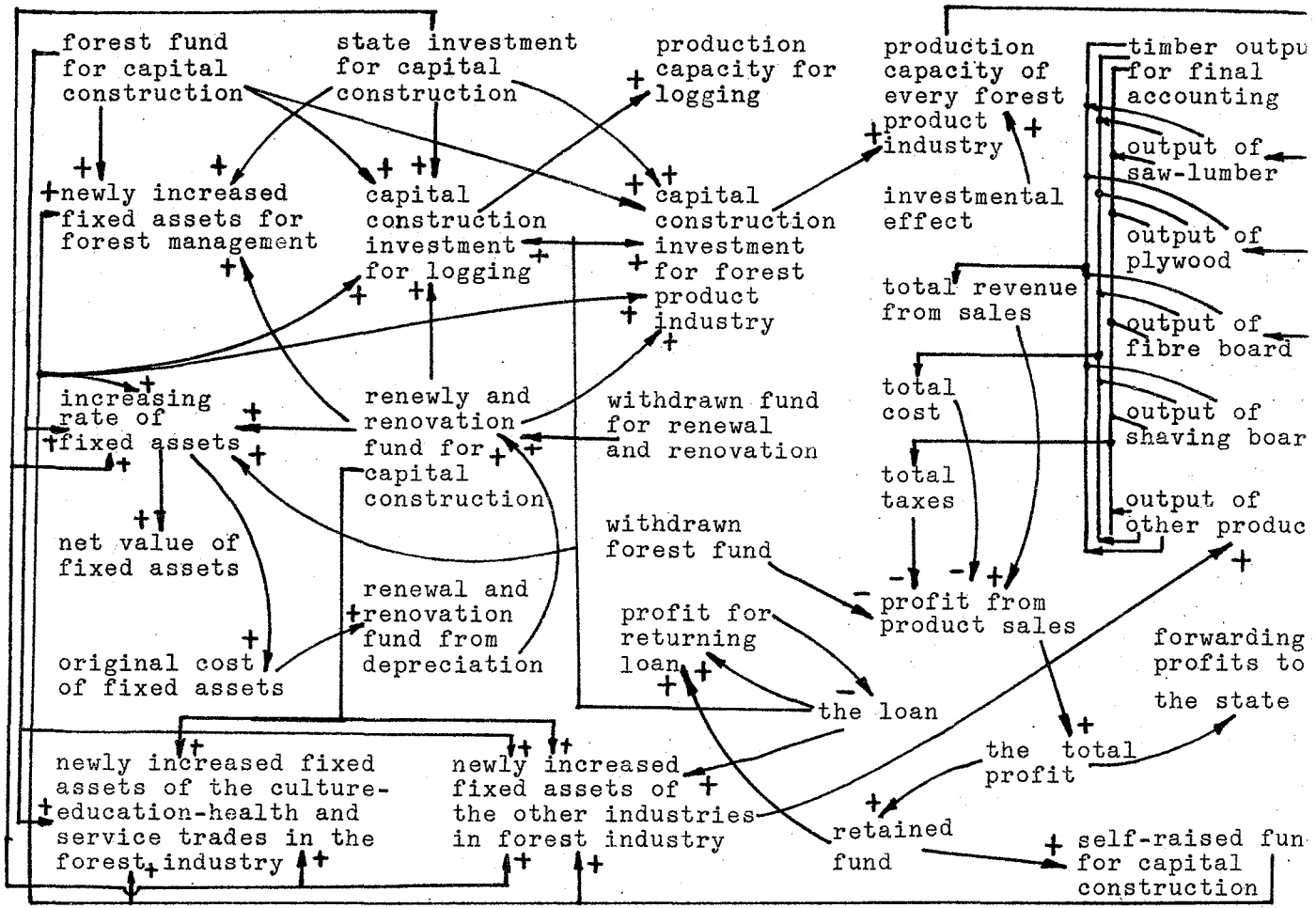


Figure 2 The Causal Relationships of the Major Variables
(The Continuation of the Figure 2)

3.1 The Submodel of the Growth-and-Decline of Forest Resources

The submodel of the growth-and-decline forest resources mainly describes the proceeding of the utilization and the reproduction of forest resources.The part of the forest resources utilization includes two sections:the rational use(the normal felling)and the irrational use(reckless felling and the loss caused by others), while the part of forest resources reproduction is mainly achieved through the reforestation and the rising of the forest management level.

A. The Section of the Forest Resources

In this part of the model,the variables describing the quantity of the forest resources are the area of the unclosed forest land, and the areas and the growing stocks of the young growth land,the middle-aged forest land,mature forest land and the secondary forest land.The relations among all sorts of forests may change in the following way:

1) The reduction of non-stocked land caused by reforestation increases the area of unclosed forest land;
2) The reduction of unclosed forest land caused by closing increases the area of the young growth land;
3) The decreasing of young growth caused by growing increases the area of middle-aged forest;
4) The decreasing of middle-aged forest caused by growing increases the mature forest land;
5) The decreasing of middle-aged forest land caused by careless tending felling increases the secondary forest land;
6) The decreasing of the mature forest land caused by clear felling increases the non-stocked land;
7) The decreasing of the mature forest land caused by selection felling increases the middle-aged forest land;
8) The decreasing of the mature forest land caused by nonstandard selection felling and reckless cutting increases the secondary forest land;
9) The decreasing of the secondary forest land caused by improving increases both the young growth land and the unclosed forest land;
10) As a result of fire,disease and insectpest and so on,the loss of the unclosed forest land,young growth,middle-aged forest and the mature forest increase the area of non-stocked land.

The utilization and reproduction of the forest resources are descrided by the changing relations of all the various forest land.

Here,taking the calculation of the area of the mature forest land as a example,we shall represent the calculating procedure of the quantity of the forest resources.The formulations of calculating the mature forest land are:

AL5.K=AL5.J+DT*(AR6.JK-AR8.JK-AR9.JK-AR10.JK-ARS5.JK-AR11.JK-
-AR13.JK) 3-1,L

where

AL5-- mature forest land (hectare)

AR6-- growing rate from middle-aged to mature(hectare/year)
AR8-- selection felling rate (hectare/year)
AR9-- clrar felling rate (hectare/year)
AR10--fire damage rate (hectare/year)
AR11--reckless felling rate (hectare/year)
AR13--nonstandard selection felling rate (hectare/year)
ARS5--other damages rate (hectare/year)

The following is the formulation of calculating mature forest growing stock.

AA21.K=AL5.K*AC23.K 3-2,A

where

AA21-- mature forest growing stock (cubic metre)
AC23-- average hectare growing stock (cubic metre/hectare)

In this formulation,the variable AC23 increases and tends to be saturated,as the cost of forest-tending and the level of forest tending grow.

B. The Section of Timber Production

The timber production section describes the possible output of timber production under the condition of certain forest resources. The principle of the controlling of the output is that cut must be lower than increment.

When the total growing stock of forest resources has been calculated,the increment of the forest resources can be calculated with the following formulation:

AA23.K=GT1.K*GTC1.K 3-3,A

where

AA23--total increment of the forest resources(cubic metre/year)
GT1 --total growing stock (cubic metre)
GTC1--integrated increment rate (percentage/year)

The integrated increment rate in the formulation is a variable.As the forest-tending level grows,its value will increase and wil be represented by a table function in the model.

In order to define the actual felling quantity in this model,we should first calculate the exploitable growing stock of final felling according to the principle that"the cut is equal to the increment".The exploitable growing srock of final felling is the maximal felling amount of certain forest resources,and it can be calculated in the following formulation:

AA24.K=AA23.K*AC25-A23.K 3-4,A

where

AA24--exploitable growing stock of final felling (cubic metre/year)
AC25--proportion of the timber forest (percentage)

In practic,in order to realize the goal of sustained-yield utilization of certain forest resources,the felling quantity should be further controlled,especially,when the forest resources have been overcut.The actual final felling growing stock must be lower than the exploitable growing stock of final felling.

In the model,the function of the controlling cut is realized th-

rough the policy variable.The policy variable is a function of time, its value is between one and zero.The actual final felling growing stock is equal to the product of exploitable growing stock of final felling and the policy variable,that is

AA28.K=AA24.K*AA27.K 3-5,A

where

AA28--actual final felling growing stock (cubic metre/year)
AA27--policy variable (cubic metre/year)

The AA27 in the equation is a table function as follows:

AA27.K=TABHL(TAA27,TIME.K,1980,2030,10) 3-6,A
TAA27=1/0.85/0.8/0.78/0.75/0.7 3-7,T

When the AA27 is equal to one,the actual final felling growing stock will be equal to the exploitable growing stock of final felling,but it will not.The reason that the AA27 will take smaller and smaller is that the proportion of young growth and middle-aged forest land get larger and larger in the forest industry system discussed.If we produce so timber according to the principle that cut must approximate increment,we can not realize the goal of sustained-yield utilization.The AA27 is an important variable controlling the quantity of the timber production,its value greatly influences the forest industry production.

The timber products,in this model,is composed of two parts:the final felling output and the amount of timber produced by thinning.The final felling output is mainly limited by the both of the resources and the capacity of logging.

C. The Section of Reforestation

In the real world,various factors influence the reforestation. Here we only consider the funds for the reforestation,the cost, the survival percentage and the non-stocked land.In the respect of the organizational forms,we only consider three forms:the state-operated forest farm,the collective and private reforesting and the natual regeneration.

3.2 The Submodel of Fund Management

In this submodel,the factors mainly considered are the following:the sale volumes of logs,saw-lumber,plywood,shaving-board and other wood products;and the variables such as sales revenues, production costs,taxes,the total profits and some other special-purpose funds.Here we assume that the demand for logs and other wood products in the society is far larger than the outputs respectively,this means that the sale volume is equal to the output; and the output of the main products is basically determined by the production capacity applied in reality,but restricted by the log output and the amount of slash.The raw materials of plywood and saw-lumber,for example,are logs,so the output of these two sorts of products must be restricted by the logs output.

The submodel,through the calculation of the sales revenues,production costs and the taxes of various products,calculates the possible profits and possible funds for special purposes and exp-

anded reproduction in the forest industry for each year.Here the profits are divided into three parts:the part of the redemption of loan,the part turned over to state and the part self-retained. The capital construction fund from the self-retained part is the main source of the self-raised capital construction fund;the forest fund drawn from log sales is divided into remitted forest fund and the self-retained forest fund,the self-retained forest fund is the main sources of the forest planting fund and the fund of capital construction for planting;the fund drawn for the renewal and renovation is also divided into two parts:the part for transformation and energy and the part for capital construction.Note that the latter is used,as capital construction,in the forest industry system.The average price,cost and the tax per unit for each sort of the products in the model are function of time,they are represented with table functions and their specific values will have significant influences on the fund for expanded reproduction in the forest industry system.

3.3 The Submodel of Capital Construction

This submodel mainly considers the funds provided for capital construction,the proportion of the invesments of all kinds of trades,the scales of newly-added fixed assets of some trades,the production capacities,the scale of the fixed assets of the forest industry system and so on.The source of the capital construction fund consists of the state investment,self-raised fund,the renewal and renovation fund for capital construction,the forest fund for the capital construction and the loan.Among them,the renewal and renovation fund,the forest fund and the self-raised fund for capital construction are produced inside the system,while the state investment and the loan are input variables.In this model the loan is mainly used in the timber production,forest products and other industries,the state investment is approximately the same as the remitted profit of the forest industry system.with the policy analysis the different effects on the development of the forest industry system,caused by different values of investment,are tested.Note that the investment used in the model before 1983 is the actual values,while the investment after 1984 is an estimated values.Here we divide the forest industry system represented by our model into five major trades:reforestation, logging and transportation,timber processing,and the other industries as well as the culture-education-health and service.And the timber processing can be further divided into saw-lumber production,plywood production,fibre board production,shaving board production and comprehensive utilization production.

This submodel focus on the distribution of various capital construction funds and the formation,depreciation and diminution of the fixed assets.Based on the above discussion,under the condition of the limited funds for capital construction the submodel describes the effects on the development of the forest industry production and the profit that can be realized.These effects are caused by different investing plan,different period of the capital construction and the different investment efficiency.At the same

time,the model also can be used to discuss the proper approach of realizing the goal of the profit that is to be achieved by the forest industry system by the end of this century,as well as the departments and trades that should be given the priority to the developing.

## 4. POLICY ANALYSIS BASED ON THE SYSTEM DYNAMICS MODEL

This system dynamics model of the forest industry system is formed organically with three submodels discussed above.In the study we can use this model to carry on simulation for various policies and developing trategies.Having limited space,we can only represeent some of the typical simulations of policy analysis.

### 4.1 Policy Analysis for Utilization and Management of the Forest Resources

In this section,in terms of the simulations of the system dynamics model,two different policies that may infleunce the tendency of growth-and-decline of forest resources are analysed.The policies used in the simulations are:

1) Keeping,basically,the present forest-tending level,and having the cut approximately equal to the increment;
2) Keeping on rising the forest-tending level,and make the cut lower than the increment.

When the first policy is followed in the simulation of the forest industry system, the condition for the model simulation is,basically,same as that for the basic model simulation.In this case,the tendency of the changing of the forest resources are that the young growth land keeps on increasing,before 2014,and then tends to decline;that the middle-aged forest land increases throughout;that the mature forest land declines to the lowest point of 590,000 hectare in2052,and then tends to grows; that the total timber production tends to decline until the lowest point of 10,880,000 cubic metre,and then begins to going up after 2010.From the results of the simulations,we can see that if the total output of timber production maintains under 11,000,000 cubic metres,the goal of getting sustained-yield utilization can be achieved.However,it is impossible in reality,because in the mature forests there are natural protective forests,seed stands and other intouchable resources.(e.g in 1983,the natural protective forests and the seed stands are 440,000 hectare,and they are intended to grow)

When the second policy is used in the simulation,the condition for the model simulation will change.The changings are mainly following:

1) Increase the cost of reforestation and forest-tending;
2) By means of rising the tending level of the forest resources, increase the growing stock per hectare,the integrared increment rate and the increment of forests,and shorten the maturity of forest;
3) According to the principle that the cut must be lower than the increment,control the felling amount.

In these cases,the changing tendencies of the forest are that (1)

the young growth forest land tends to going up before 2008 and then begins to decline,the maximal value is 3,040,000 hectares;(2) the middle-aged forest land grows throughout and the maximal value is 5,550,000 hectares;(3) the mature forest land,before 2032, tends to decline and the minimal value is 700,000 hectares,then going up;total increment,thinning outturn and the growing stock of final felling are generally rising;total output of the timber is going up before 2028,then is stably remaining at a value of 20,000,000cubi-metre.From the results of the simulation,it is clear that the second policy is better than the first one,because it can not only realize the goal of getting a sustained-yield forest resources for utilization,but also raise the output of the timber production.For the purpose of comparison,the results of the two simulations are drawn in figure 3.The non-stocked land is also drawn in the figure,just as the description above,the time for the non-stocked land(2) diminishing to zero is about 20 years later than that for the non-stocked land(1),it results from lack of fund caused by the changing of management methods from the extensive to the intensive.

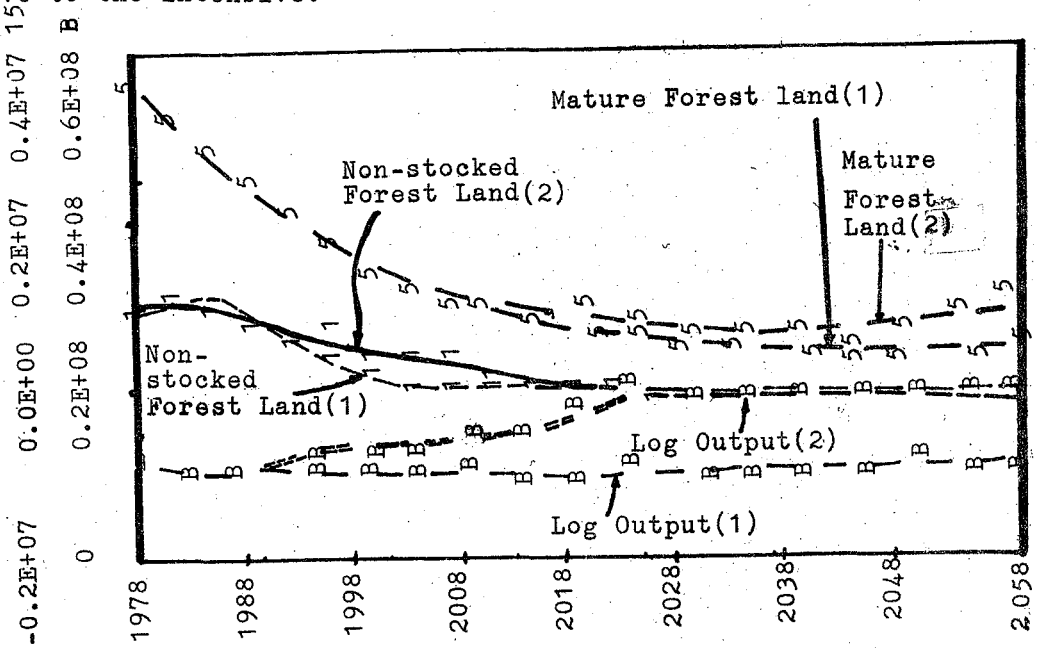


Figure 3: The results of the two simulation ((1) and (2),respectively,represent the results of the first and the second policy.)

4.2 Investment Policy Analysis for the Capital Construction

From the above analysis,we can see that the timber production won't grow much in the near future because of the limitation of the forest resources,so,in order to realize the goal of providing

more wood products for the country,the forest industry system should devote greater efforts to developing the forest products trade ,especially pay more attention to the wood comprehensive utilization industry.Since the industrial basis for wood comprehensive utilization is rather poor,the forest industry system should make more efforts in the capital construction of this industry.

Having limited fund for the capital construction of the forest industry,we should give consideration for the development of other trades,while giving priority to the development of wood comprehensive utilization industry.Therefore,we,in this section,mainly analyse the possible development tendency of wood comprehensive utilization under the condition that the state investment for the capital construction,before 2000,is basically equal to the profit turned over to state by the forest industry system,and is maintaining 250 million yuan after 2000.The tendency of changing the production capacity of fibreboard and shaving board is drawn in figure 4.If the preceding policy is adopted,the production capacity of fibreboard and shaving board will grow repidly before 2000,and then it will grow slowly and tend to stability at last.In the case that the utilization ratio of the slash and scrap materials is lower,increasing the amount of investment can raise its production capacity quickly,and can also raise the capacity of comprehensive utilization;and because of the restriction of the total amount of the slash and scrap materials,the investment will be diminished gradually later to slow the developing speed.It has been calculated that the production capacity of fibreboard and shaving board will reach,respectively,630,000 cubic metres and 340,000 tons in 2000;while the investment for shaving board will amount cumulatively to 197 million yuan.Because of the limitation of the capital construction fund,their production capacity grows slowly before 1990.

4.3 The Policy Analysis for the Wood Price

The present price structure for the wood products is quite unreasonable.The log price is too low and the cost of forest-planting is not included in the price.As a result,there is a obvious gap between the price and the value,which influences the development of forest industry seriously.For this reason,the forest department has put forward a proposal that the log price should be risen in our country.(The average price of each cubic metre should raise 37 yuan.)

In this section,our simulation analyse the stimulating effect on the forest industry production,if the price of each cubic metre log raise 20 yuan from 1985 (10 yuan added to the forest fund, 10 yuan for the cost value of forest).(In the simulation,we also adapt the price,cost and tax of the saw-lumber and the plywood.) The stimulating effects are mainly following:

1) Rising the reforestation expense will speed up the reforestation rate;comparing with the system in section 4.1,the work of reforestation on the non-stocked can be done 28 years earlier.
2) Under the condition that the minimal value of the mature

forest land rises 4 percent,the output of log will rise 3 percent.

3) Increasing the capital construction fund can speed up the development of the wood comprehensive utilization industry, and to some extent,raise the production capacity,at different level,of all kinds of wood products.

4) The total profit increases strikingly,comparing the simulation result in figure 4.

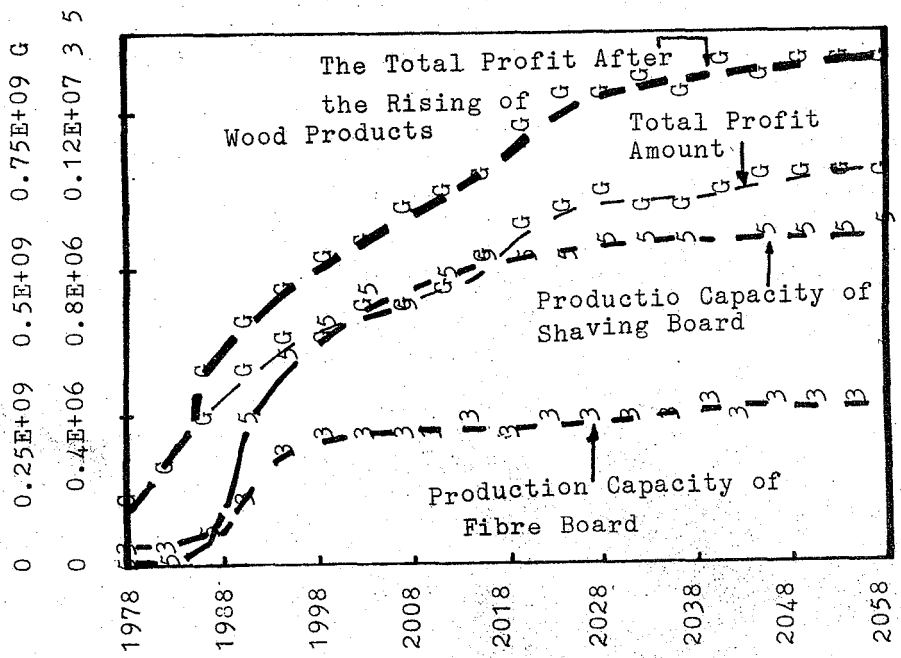


Figure 4:Partial results of the simulation of the submodels of capital construction and fund management

## 5. CONCLUTION

By analysing the simulation results,we can draw the following general conclution:1) The forest resources is the most important restricting factor of the whole forest industry production,and the most important approach to increase the forest resources is to change the management and administration from the extensive to the intensive.However,under the condition that the forest management fund chiefly comes from the forest fund,as the proportion of drawing the forest fund is relatively small and the log output is not high,the forest management fund is consequently less and can not meet the needs of accelerating the speed of the reforestation and of rising the level of forest-tending(e.g according to the developing project,by 2000 year,theincrement rate of the forest should be promoted by 100%,but in this model it only rises by 40%); 2) The present wood sale price is too low and in turn the profit of the forest industry system is also very low,which can not meet

the demand of the expaned reproduction of the forest industry system.Hence,the rising of log price by about 20 yuan per cubic metre will have certain facilitating effect on the fine-circle of production of the forest industry system,anyhow,the problem can not be solved completely;3) The capital construction investment is too low before 2000,it can not meet the needs of the forest industry development significantly.(e.g The output of the shaving board should be 1.3 million cubic metres,required by the project,in 2000,but the number given by our model is only 630 thousand cubic metres.) So the forest industry should be given more supports by the government.

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